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Gas warfare

Edward Samuel Farrow

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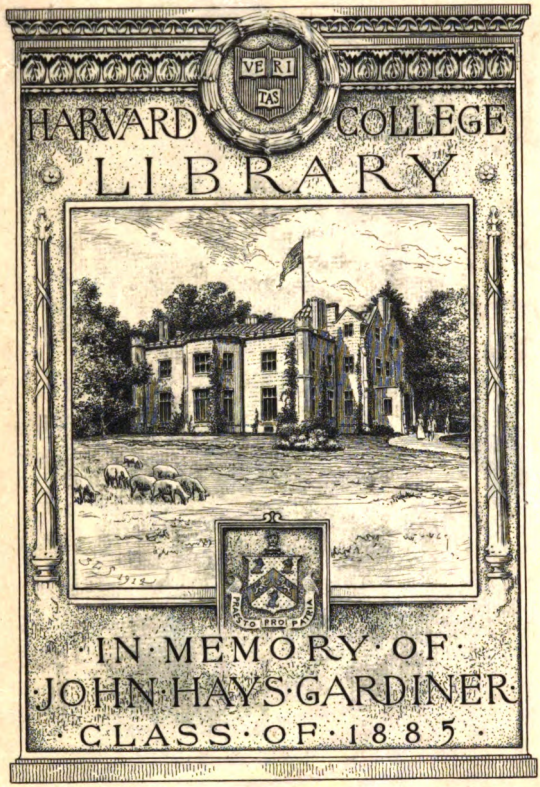

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GAS WARFARE

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GAS WARFARE

BY

EDWARD S. FARROW

LATE ASSISTANT INSTRUCTOR OF TACTICS, AT THE
UNITED STATES MILITARY ACADEMY, WEST POINT, NEW YORK

Author of Farrow's "Military Encyclopedia," "American Small Arms,"
"Dictionary of Military Terms," "Manual of Military Training,"
"Riots and Riot Duty," "American Guns in the
War with Germany," Etc.

"What is obvious is not always known,
what is known is not always present."
—JOHNSON

NEW YORK
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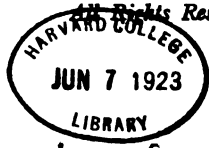

Gardiner Fund

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THIS WORK

IS INSCRIBED BY ITS AUTHOR

TO

THOSE MEN WHO WITHOUT DEFENSE

BORE THE BRUNT OF

THE FIRST GAS ATTACK

AT YPRES

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PREFACE

Concentration, surprise in tactics, and the use of unexpected new materials are three most important things in Gas Warfare. With the first gas attack, the whole course of the war with Germany changed. This attack was made against men who were entirely unprepared and absolutely unprotected, and it was no exaggeration when the Germans claimed that 6,000 of our men were killed and as many taken prisoners. Never had such a battlefield been seen in warfare, ancient or modern.

The official records show that in the war with Germany the casualties from gas equaled 2½ per cent, while those from bullets and high explosives equaled 25 per cent, thus demonstrating that gas is a most humane weapon of war. The early gas clouds soon gave way to gas shells, the most effective materials for the latter being mono- and trichloromethyl-chloroformate. Prussic acid was little used as it was rated lower than phosgene in toxicity.

I believe that gas and military aeronautics will play the principal parts in the next war, which will be literally finished in the chemical laboratory. I have, therefore, prepared this volume to assist in educating our soldiery in the use of gas in both defense and offense. I am indebted to Generals Wil-

* The proportion of deaths to casualties

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liam L. Sibert and Amos A. Fries, who led in actual gas warfare against the Germans, and to other officers with whom I have conferred.

EDWARD S. FARROW.

New York City, May, 1920.

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GAS WARFARE

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GAS WARFARE

CHAPTER I

War Gas Investigations, Bureau of Mines Activities, Gas Masks and Rescue Apparatus, Research Work, Lethal and Neutralizing Substances, Toxicity Tests and Divisions of Chemical Warfare Service.

In February, 1917, when war between the United States and Germany seemed inevitable, the Bureau of Mines took up the question of what it could do to most advantage in the event of war. Since its establishment in 1910, it had maintained a staff of investigators studying poisonous and explosive gases in mines, the use of self-contained breathing apparatus for exploring mines filled with noxious gases, the treatment of men overcome by gas, and similar problems. At a conference of the director of the bureau with his division chiefs, in February, 1917, the matter of national preparedness was discussed, and especially the manner in which the bureau could be of most immediate assistance with its personnel and equipment. One of the things decided was to investigate gas masks and rescue apparatus for military and naval purposes.

Beginning with an investigation to develop the best type of gas mask, the scope of the work ex-

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tended until it included researches relating to a wide range of devices, such as different types of poisonous and irritating gases and smokes, smoke screens, gas shells and gas bombs, flame throwers, trench projectors for firing gas bombs, signal lights, and incendiary bombs. The development of special oxygen breathing apparatus, similar to that used in mining, for naval or military use soon followed.

The National Research Council was at once organized to act as an intermediary on research between the scientists and the Universities of the country and the various departments of the government and to suggest and consider research problems. By June 30, 1917, the personnel engaged in research work comprised 50 paid investigators, and the work had expanded from the devising of gas masks to the study of poison gases and chemical appliances for offensive warfare. One of the early results of the research work undertaken by the Bureau of Mines was the establishment of the chemical service as a unit of the National Army. Colonel William H. Walker commanded the American branch of the Chemical Service, reporting to the Gas Warfare Division and the Chemical Service Section in France. Subsequently Colonel Walker was transferred to the Ordnance Department and put in charge of enormous plants for making chemicals for gas warfare that were erected at Edgewood Arsenal. The establishment of this unit was a noteworthy fact in the history of applied chemistry, for never before in any war or in any country had chemistry been recognized as a separate branch of the military service.

By May, 1918, the question had arisen as to

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whether the research work on war gases should be transferred to the War Department or should continue under the Bureau of Mines. Army officials believed that the work could be coördinated better by having it under military control. On the other hand it was held that there was nothing to be gained by a transfer of authority as the research work had kept well in advance of the manufacturing development in progress under the War Department and the development of methods of manufacture had been conducted so expeditiously that the supply of toxic materials exceeded the supply of shells. The counsel of those Army officers who believed the research work should be transferred to the War Department prevailed, and on June 25, 1918, under the authority given by what is known as the Overman Act, President Wilson transferred the work being done at the Amercan University from the Bureau of Mines to the Chemical Service of the Army.

For the purposes of study and research the war gases, many of which are liquids at ordinary temperatures and pressures, were divided into two general classes (*a*) lethal substances, generally those that kill by asphyxiation, and (*b*) neutralizing substances. The neutralizing materials are less poisonous but are capable of putting men out of action for shorter or longer periods of time. To this class belong lachrymators (or tear gases), sternutators (or sneezing gases), and eye, lung, and skin irritants, which inflame the eyes, cause severe respiratory distress, and blister the skin. Absorbent substances like charcoal, soda lime, sodium phenate, hexamethylamine tetramine, caustic soda, zinc oxide, etc., absorb or neutralize such gases as chlorine,

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phosgene, prussic acid, chlorpicrin, mustard gas, or xylyl bromide, and when used in gas masks protect against finely divided toxic solids such as diphenylchlorarsine; special clothing is needed for protection against skin irritants such as mustard gas.

In order to be deemed worthy of large-scale manufacture a new gas had to possess some quality or qualities that rendered it decidedly better for military use than its predecessors. It had to have high lethal value, be a powerful lachrymator or a good sternutator, or vesicant, or be more highly penetrative. The materials for its manufacture had to be plentiful and the process of manufacture could not be too difficult. When a new gas was under investigation the procedure was about as follows: In the laboratories its physical, chemical, and physiological properties were determined, and methods of preparing it were investigated; then a plant for small-scale manufacture was designed. The gas was examined to determine how readily it penetrated the American, English, French, and British masks. Also, tests were made to determine the best way of serving it to the enemy, whether in shells or from cylinders. In the meantime a thorough search was made for raw materials, for its manufacture. If all investigations proved satisfactory, it was turned over to the Ordnance Department—either to the development division, to build the first large unit, or to the gas manufacturing division. Chemists from the research division, who were familiar with the process of manufacture, were transferred along with the latter when it left the research division. As soon as the research staff had completed work on some of the more important substances, larger

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plants were designed for manufacturing the materials in quantities at the Edgewood Arsenal.

Research to determine changes that take place in the body as the result of exposure to lethal gases, and thus to devise methods of treatment for gas poisoning, was organized at Yale University in May, 1917. After the pharmacological and toxicological research work was moved to the American University Station, therapeutic work was continued in the laboratories at Yale. For studying the organs and tissues of animals killed in gassing tests, a pathological section was established in the summer of 1917 with laboratories at the American University Station and at Yale University. Among the problems attacked by the pathological division was the effect of mustard on the mucous membrane of the eyes and respiratory organs and on the skin. The pharmacological division was established at American University in November, 1917, and in July, 1918, it became the pharmacological research section of the Chemical Warfare Service. The work of this division comprised the following investigations: 1. Devising toxicity tests by exposing mice, guinea pigs, rats, rabbits, cats, and dogs to poison gases, and by studying the pharmacological and toxicological effects. 2. Testing tear gases and sneezing gases on men. 3. Determining the skin-irritant effect of gases. 4. Testing fabrics for their permeability to mustard gas. 5. Devising analytical methods for the control of the concentration of the gases used in tests. 6. Determining the sensitivity to gas of the skin of different individuals.

Toxicity tests with animals covered a long list of poisonous liquids and vapors. Many of the tests

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with dogs were for varying lengths of time to determine the relation between the lethal effect and the concentration and length of exposure. Tests were also made with animals in a bomb pit at the American University station and at the Indianhead Proving Ground to determine the effective area of shells charged with the different toxic substances. A large number of fabrics were tested for permeability to mustard gas, both dogs and men being used in the tests, and results of the tests were transmitted to the Army and Navy. Many tests with men and animals were made to determine the effectiveness of tear gases and the minimum concentration at which these gases could be detected by their odor or their irritating effects. One result of these tests was to show that man was more than one thousand times as susceptible to tear gas (xylyl bromide) as the horse, and more than ten times as sensitive as the dog.

The pyrotechnic division was organized in June, 1917. Among the tasks undertaken by its *gas-shell section* was the determining of the stability of various gases and toxic solids when used in shells. This section devised a training bomb for use by the gas-defense officers in cantonments, and studied lachrymatory bombs, smoke bombs, and *noise* bombs. Also, several gas-producing chemical combinations were submitted to the Bureau of Ordnance of the Navy for use in armor-piercing shell. The *smoke-screen section* prepared specifications for a Navy smoke funnel and a smoke-box float; it also perfected a smoke signal for airplane bombs that was accepted by the Ordnance Department, also a similar device for use in the Navy dummy airplane

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bomb. A portable smoke apparatus using silicon tetrachloride was designed for the Army, a smoke mixture of phosphorus and TNT, for use in shells and in candles, a smoke bomb of the Liven's type, a smoke grenade, and a "noiseless" nozzle for gas attacks. A method of using oleum (fuming sulphuric acid) to produce a smoke screen was accepted by the Navy. A new form of Stokes mortar was designed that gave greater accuracy and longer range. A long series of tests with Liven's projectors and projectiles were made to reduce the weight of the unit and to increase the range. The *hand-grenade section* was organized at the American University Station in October, 1917, to continue work on grenades, but as the grenades already adopted by the Army were standardized, the section took up the testing of explosives used in pyrotechny and in gas warfare, and later, testing of high explosives. The sensitivity in use of various picrates was studied in order to assure proper safety measures in storing and handling being taken at the plant making chlorpicrin, for the Ordnance Department. Fragmentation tests were made of hand grenades charged with TNT, amatol, and victorite, the last a chlorate explosive; the results were forwarded to the Army and the Navy. Preliminary studies were made of the properties and usefulness of parazol and other chlornitro products as explosives. Studies of chlorate and perchlorate explosives led to the finding of satisfactory chlorate and perchlorate powders for use in hand grenades. A new explosive called anilite, which employs liquid NO_2 as an oxidizing agent, and used by the French, was studied. After July 1, 1918, the hand-grenade section was desig-

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nated the explosives section of the Chemical Warfare Service. The *incendiary section,* organized as a separate unit in October, 1917, perfected a scatter type of bomb for the Army, devised an incendiary dart to be used from airplanes, an incendiary projectile for use with the Liven's gun, and prepared recommendations for the Signal Corps as to the best type of explosives to be used with an airplane destroyer. After July 1, 1918, the section was reorganized as the inorganic section of the Chemical Warfare Service. The *flaming-liquid* section designed and perfected two portable flaming-liquid guns. Tests to determine full mixtures for use in connection with the flaming-liquid guns were made and recommendations submitted to the Ordnance Department of the Army. The *signal-light* section conducted a thorough investigation of green flares, devised several colored smokes for use in connection with land signals and air signals, studied methods of improving the white flare, designed an illumination float to be dropped from an airplane, and constructed a special device to be used by submarines in signaling to surface craft. The *laboratory section* carefully studied linings, packings, and cements for gas shell. A shell that uses a special type of lead lining was recommended to the Ordnance Department of the Army. Other work included the development of a systematic method for analyzing pyrotechnic materials, and a thorough laboratory study of the usefulness of paper and pulp containers for powder. The recommendations submitted were adopted by the Ordnance Department, which had the tubes made in large quantities by June, 1918. The miscellaneous section designed a

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smoke shell for the Navy, tested a special shrapnel shell with special loading for the Chemical Service of the Army, and made tests of silicon tetrachloride, stannic tetrachloride, and titanium tetrachloride for smoke grenades, to determine which smoke is the most obnoxious.

The dispersoid division was established in April, 1918, to study the small-scale production of smokes or mists and the best way of protecting men against them. Among the apparatus developed was a Tyndall meter for determining the rate of dissipation of smokes under varying conditions. Tests were started to obtain systematic data on the toxicity and rate of dissipation of smokes, and rate of penetration through filters and mask canisters. One of the problems taken up was the development of smoke candles. Besides the work on smokes, the dispersoid division continued some of the work on primers that was started at Urbana, Ill., using the Tolman hangfire measurer. Routine tests of airplane ammunition were made with this machine for the Ordnance Department.

One of the largest of the branch laboratories engaged in the study of war gases was that of the Catholic University at Washington. The work done there included the study of various problems in organic chemistry under the direction of Dr. W. K. Lewis; investigations of smokes and mists (dispersoids) under Dr. R. C. Tolman; and the study of various problems of physical chemistry under Dr. W. D. Bancroft, including catalytic investigations, such as the catalytic action of charcoal, the production of fluorine and fluorine compounds, the conversion of phosgene into superpalite, and the oxi-

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dation of alcohol to acetic acid. At Clark University Dr. C. A. Kraus worked on the dimming of eyepieces of gas masks; on metal Dewar flasks for providing liquid oxygen for aviators and submarines; on the stability of gases; on a heat interchanger for use on submarines; and on boosters for gas shells. At Yale University Dr. T. B. Johnston had charge of a staff of organic chemists that worked chiefly on the halogen ethers, on hydrogen selenide, and on certain selenocyanides. At Bryn Mawr Dr. R. F. Brunel studied the preparation of diazomethane and chlor and brom ketones. At Ohio State University Dr. C. A. Boord worked on mustard gas, phenylchlorarsine, diphenylchlorarsine, and on the selenium and tellurium derivatives of mustard gas, which for a time threatened to displace mustard gas. At Harvard University Dr. G. P. Baxter did much work on the physical constants of the war gases, especially their vapor pressures, thus supplying data that were essential for the proper use of these materials. Dr. E. E. Reid, of Johns Hopkins University, who became a consulting chemist of the Bureau of Mines in May, 1917, helped in interesting the chemists of the country in the work on noxious gases, and in having them submit organic preparations. He had charge of a group of investigators working on problems of organic chemistry at the university. Dr. Reid Hunt, at Harvard University, with a staff of pharmacologists, investigated toxicological problems. Dr. G. A. Hulett, head of the department of physical chemistry at Princeton University was sent abroad in April, 1917, as a member of a commission appointed by the National Research Council to gather data on

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technical war problems. He gave especial attention to the use of noxious gases in warfare, and brought back information that proved of immense value.

In research as in the manufacture of gases and masks, the United States was without a peer. Gas intelligence, developed along with other lines of work, reached every part of the American Army and won not alone the respect and confidence of the general staff but of the Allied Armies as well. The Gas Regiment, which was handled directly by the Chemical Warfare Service in conformity with General Battle orders, did work second to that of no other American regiment. It gassed the enemy heavily with Livens projectors and 4-inch stokes mortars, and did marvelous work with phosphorus and thermite in cleaning up machine gun nests in all the large battles of the Americans. No less important was their work with smoke materials for screening troops in launching large attacks. The Chemical Warfare Service in the field made great strides and went far beyond expectation in developing methods of attack, methods of protecting troops and in teaching the Army not alone how to defend itself against the enemy gas, but how to send that gas back at him more efficiently than he sent it over.

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CHAPTER II

Toxic Gases, Early Employment in Warfare, Development in the War of 1914-1918, the Edgewood Arsenal, Chlorine Plants, Chlorpicrin Plants, Phosgene Plants, Mustard Gas Plants, Filling and Spray Painting Plants, Chemical Warfare Production Data.

Suffocating gases were first used in warfare in the year 431 B. C., when sulphur fumes were employed in besieging the cities of Platea and Belium in the war between the Athenians and the Spartans. Numerous similar uses of toxic substances are recorded throughout the Middle Ages. In 1855, the English Admiral Lord Dundonald, having observed the deadly character of the fumes of sulphur in Sicily, proposed to reduce Sebastopol by sulphur fumes, and the details of the proposition were carefully worked out. The English Government disapproved the proposition on the ground that "the effects were so horrible that no honorable combatant could use the means required to produce them." The probable use of poison gases continued in the minds of military men and at The Hague Conference in 1899 several of the more prominent nations of Europe and Asia pledged themselves not to use projectiles giving out suffocating or poisonous gases. Germany signed and ratified this declaration in September, 1900, but the United States declined to sign it. Admiral Mahan, a United States delegate,

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stated in substance in regard to the use of gas in shell, at that time an untried theory, that the reproach of cruelty and perfidy addressed against these supposed shells was equally uttered previously against firearms and torpedoes, although both were afterwards employed without scruple. He held that it was illogical and not demonstrably humane to be tender about asphyxiating men with gas, when all were prepared to admit that it was allowable to blow the bottom out of an ironclad at midnight, throwing hundreds of men into the sea to be choked by the water, with scarcely the remotest chance to escape. The Second Hague Peace Congress in 1907 adopted rules for land warfare, the 23d article of which read as follows: "It is expressly forbidden to employ poisons or poisonous weapons."

The use of toxic gas in the European War dates back to April 22, 1915, on which day the Germans employed chlorine, a common and well known gas, in an attack against the French and British lines in the northeastern part of the Upper Ypres Salient. The methods of manufacturing toxic gases, the use of such gases, and the tactics connected with their employment, were new developments of this war. During the year 1918 from 20 to 30 per cent of all American battle casualties were due to gas, showing that toxic gas is one of the most powerful implements of war. The records show, however, that when armies were supplied with masks and other defensive appliances, only about 3 or 4 per cent of the gas casualties were fatal. This indicates that gas can be made not only one of the most effective implements of war, but one of the most humane. It will, of course, be necessary to remove the noncombatant

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population from a greater depth of country immediately in the rear of the fighting lines than formerly, in order that women and children may not be gassed. This additional sacrifice of territory for war uses is another element of effectiveness in the weapon.

The use of toxic gas in warfare by Germany compelled the allied nations to adopt like tactics; accordingly England and France, faced with the desperate situation resulting from advantages secured by the Germans through the employment of these new weapons, immediately turned their attention not only to devising methods for protecting their own troops, but also to securing supplies and equipment necessary for the utilization of toxic gas as an agent of warfare against the German Army. Germany originated thereafter the use of most of the new forms of gas, but the allied nations and America were actually producing, at the time of the armistice, gases on a much greater scale than Germany was ever able to attain. In fact, America itself was producing gases at a rate several times as great as was possible in Germany.

In the early days of the belligerency of the United States the need of a plant for filling artillery shell with toxic gases was felt, and in the fall of 1917 the Government purchased a large tract of land near Aberdeen, Md., to be an artillery proving ground. Approximately 3,400 acres of this reservation, about one-tenth of it in area, was set aside as the site for the gas shell-filling plant. This reservation was known as Edgewood, and the plant erected on the site was called the Edgewood Arsenal. Work started on the Arsenal construction November 1, 1917. By December 1, 1917, it was decided to build at

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Edgewood a chlorpicrin plant and a phosgene plant. In March, 1918, the Edgewood project was taken from the Trench Warfare Section of the Ordnance Department and made an independent division under the command of Colonel William H. Walker. In June, 1918, the Chemical Warfare Service was organized, and the Edgewood Arsenal was transferred to it. General William L. Sibert, Director of the Gas Service, took charge of the activities of the arsenal in May prior to the official transfer.

Chlorine, the raw material for the manufacture of which is common salt, was one of the principal materials required in the gas-production program. Although chlorine was a standard product in the United States prior to the war, it was soon seen that there was an inadequate commercial supply to meet the requirements of the proposed gas offensive. Chlorine was used not only by itself, but it was also the active agent in the manufacture of nearly all the other toxic gases which were required. Consequently it was decided to build a Government chlorine plant with two 50-ton units, giving a daily capacity of 100 tons of liquid chlorine. The ground for this plant at Edgewood was broken on May 11, 1918, and the actual production of chlorine begun on September 1.

In July, 1917, the Germans introduced the so-called mustard gas. It was immediately realized that for certain purposes of fighting this chemical was the most effective product so far employed, and a large number of Government experts here at once concentrated their energies in developing methods for its manufacture on a large scale. It was decided to erect a large plant at Edgewood for the manufac-

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ture of mustard gas, the plant producing the first gas in June, 1918. It soon became evident that reliance could not be placed upon civilian labor in the operation of this plant and other chemical plants at Edgewood because of the danger involved, and it was decided to utilize enlisted men in the working crews. As the projects at Edgewood increased in size and number, the forces at the arsenal grew, until at one time there were 7,400 troops at this point. In the spring of 1918, various scattered factories by official order were made part of the Edgewood Arsenal, each plant being designated by the name of the city or town where it was located. Thereafter in Army usage the term "Edgewood Arsenal" embraced not only the group of factories on the Edgewood reservation, but also included projects at Niagara Falls, N. Y., Midland, Mich., Charleston, West Va., Bound Brook, N. J., and Buffalo, N. Y. In addition to these, the Edgewood Arsenal built at points advantageous to supplies of raw materials four other plants at Stamford, Conn., Hastings-on-Hudson, N. Y., Kingsport, Tenn., and Croyland, Pa., and operated them as well.

In constructing and equipping the Edgewood Arsenal the Government laid 15 miles of narrow-gauge railway and 21 miles of standard gauge railway, built 15 miles of improved roadway, and set up two water systems, one with a capacity of 1,500,000 gallons per day for the manufacturing purposes of the chemical plants, and the other providing a fresh-water supply pumped 4 miles with a daily capacity of 2,000,000 gallons; of a total of 558 buildings, 86 were cantonment buildings, with a capacity of 8,400 men, and adequate quarters for

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officers and civilian employees. Three field hospitals, a complete base hospital, and separate buildings for Y. M. C. A. and other activities indicated the extent of the building equipment. Three power houses were provided, with a total capacity of 26,500 kilowatts. In the construction of buildings every precaution was taken to avoid accidents from the handling of toxic gases, the ventilating systems being as near perfection as scientific knowledge could make them. The following table of casualties in 1918 at the Edgewood Arsenal proper shows that all of the danger of the war was not confined to the front:

Toxic agent	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Mustard gas.....	14	41	190	153	227	47	2	674
Stannic chloride..	..	3	8	15	21	3	..	50
Phosgene.....	..	..	3	7	22	17	1	50
Chlorpicrin.....	..	14	18	9	3	..	..	44
Bleach chlorine...	..	2	39	2	1	..	..	44
Liquid chlorine...	..	1	3	2	7	5	..	18
Sulphur chloride..	..	..	2	1	6	..	..	9
Phosphorus.....	..	2	7	5	1	..	..	15
Caustic soda.....	..	..	3	..	3	4	..	10
Sulphuric acid....	..	..	4	3	1	..	..	8
Picric acid.....	..	..	2	..	..	..	..	2
Carbon monoxide.	..	..	..	..	1	..	..	1
Totals.....	14	63	279	197	293	76	3	925

Chlorine was the only war gas produced on a commercial scale in America prior to the war. At the ordinary temperatures chlorine is a greenish-yellow gas of strong, suffocating odor. Through the combined effects of cold and pressure it is readily condensed to a liquid and is ordinarily shipped in this form, stored in strong cylinders. It is prepared commercially by the electrolytic process. A current

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of electricity is passed through a solution of common salt. The greenish gas at once arises, leaving behind it a residue of caustic soda. The apparatus in which the salt is decomposed by the electric current is known as a cell. The Government plant used Nelson cells, each with a capacity of 60 pounds of chlorine and 65 pounds of caustic soda per 24 hours.

The plant at Edgewood was ready for operation in August, 1918. It consisted of (1) a cell house, which had a total capacity of 100 tons of chlorine per 24 hours; (2) an electric substation for supplying the current; (3) a brine building, where the salt was mixed with water and the resulting brine purified; (4) a boiler and evaporation building, for concentrating the caustic soda from the cells; (5) a caustic fusion building, for drying the caustic soda and fusing it into solid form for shipment; and (6) a liquefying plant to condense and liquefy 50 tons of chlorine per day.

With the exception of chlorine, chlorpicrin was the first war gas to be manufactured on a large scale in the United States. When pure, chlorpicrin is a colorless liquid which boils at a temperature approximately of 112° C. The compound has been known since 1848. While not so poisonous as some of the other products used in gas warfare, it is, nevertheless, an active poison, and has the additional advantage of being a fair lachrymator, or tear producer. It is made by the reaction between picric acid and chlorine. The chlorine is best supplied in the form of so-called bleaching powder, which is ordinary chloride of lime. In the manufacturing process as originally carried out, free picric acid was mixed with bleaching powder held in suspension with

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water. Later it was found advantageous to use calcium picrate instead of picric acid. Accordingly, the final process was as follows: The bleaching powder was creamed with water and mixed with a solution of calcium picrate in large stills holding 5,000 gallons or more. A jet of live steam was then introduced at the bottom of the still, and the reaction began at once, the rapidity depending upon the amount of steam introduced. The resulting chlorpicrin, together with a certain quantity of steam, passed out of the still and was liquefied in the condenser. The resulting mixture of chlorpicrin and water was run into tanks, where the chlorpicrin, being insoluble in water, gradually settled to the bottom and was run off and used directly in gas shell.

America's supply of chlorpicrin during the war came from the Edgewood Arsenal and the American Synthetic Color Company under a contract dated December 13, 1917; and the company shipped nearly 112,000 pounds of the gas to Edgewood on March 11. This, when mixed with the necessary stannic chloride, supplies of which were already on the ground, was sufficient to fill approximately 100,000 75-millimeter shell. The chlorpicrin plant at Edgewood went into entire operation in June, 1918.

Phosgene was one of the deadliest gases employed in the European war. Numerous other gases were used to annoy the enemy and force the wearing of masks, but phosgene was a killer employed to produce as many casualties as possible. The gas did not persist long in the air or on the ground after the shell had exploded, so that it was an ideal chemical for use in an attack. The gas would clear away by

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the time the troops following reached the place of gas concentration. At ordinary temperatures phosgene is a colorless gas, but it condenses to a liquid at 8° C. It is formed by the combination of two gases, chlorine and carbon monoxide, in the presence of a catalyzer. The reaction is best conducted in iron boxes lined with lead and filled with charcoal of proper quality, into which boxes a stream of the reacting gases, mixed in proper proportions, is introduced. The reaction creates heat, and means must usually be taken to keep the reaction boxes cooled. The resulting phosgene is condensed to a liquid by passing the gas through a condenser which is surrounded by brine kept cold by refrigeration. The liquid is then stored in strong steel containers or run directly into Livens drums or artillery shell.

Because of the great importance of phosgene in warfare the Government financed phosgene plants at Niagara Falls, N. Y., Bound Brook, N. J., and other places, and decided to build a Government phosgene plant at Edgewood, the construction of which was begun in March, 1918. It consisted of four catalyzer buildings, each building having four units, each unit possessing a projected capacity of 5 tons of phosgene per day. The carbon monoxide used in the process was produced by passing a mixture of oxygen and carbon dioxide over heated coke in a gas producer, the oxygen being supplied by a Claude machine with a capacity of 100,000 cubic feet of oxygen every 24 hours. The chlorine used came partly from the Edgewood chlorine plant and partly from outside sources. The total output of phosgene at Edgewood was 935 tons, and that pro-

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duced by all plants before the armistice was 1616 tons.

The Germans, in spite of their attainments in chemistry, were never able to improve their clumsy and expensive methods of producing mustard gas. The best reports we have show that at the time the fighting ended, all of Germany's chemical warfare facilities could not produce more than 6 tons of mustard per day. The United States alone had ten times that capacity on the same date, while France and England both reached a very heavy output. Known in chemistry as *dichlorethyl sulphide,* mustard gas is a colorless, slightly oily liquid, boiling at 220° C. with some decomposition. When perfectly pure it freezes at 14° C., but, since it usually contains small percentages of impurities, it usually remains liquid at 0° C., or even below that. The first commercial process proposed for its manufacture depended upon the use of ethylene chlorhydrin. In the spring and summer of 1918 a new process was developed both in Europe and in the United States, one which used sulphur monochloride. This process consisted in blowing gaseous ethylene into liquid sulphur monochloride in large iron reaction vessels. Sulphur is set free by this reaction, and the temperature must be controlled in order to prevent the formation of solid sulphur in the reaction machine. The construction of the Edgewood plant was begun in May, 1918, and the first mustard was produced a month later. At the time of the armistice the arsenal was producing 30 tons per day. The total production of mustard gas at Edgewood during the war period was 711 tons, of which 300 tons went into shell. To in-

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sure an adequate supply of sulphur monochloride for its mustard gas production the Government built a special plant at Edgewood with a capacity of 300 tons of sulphur monochloride per day.

As soon as toxic gas warfare had developed to a considerable extent, the perfection of gas-absorbing masks had given almost a complete protection against this new weapon, if the soldier put on his gas mask in time. But the mask, especially the earlier forms of it, was not easy upon the wearer, due to the difficulty of breathing through it and also because it restricted the soldier's vision. It was soon discovered that a force compelled to wear its gas masks for any considerable period lost in efficiency. The employment of gas by both sides for the purpose of forcing the opposite sides to wear masks continually was an important element in war at the close of hostilities. For this purpose the so-called tear gases were produced. Gassing the enemy with tear gas was much cheaper than with poison gas, yet it forced him to remain masked. The tear gases were highly effective. Even a trace of tear gas in the air would in a few moments blind a man temporarily. A single tear-gas shell could force the wearing of masks over an area so wide that it would require from 500 to 1,000 phosgene shell to produce the same effect.

As most of the tear gases had bromine bases, it was early determined by the Government to increase the American supply of bromine for gas warfare requirements. The domestic source of bromine is principally in certain subterranean brines, these solutions containing bromine in its compounds. The Government financed the sinking of 17 brine wells

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near Midland, Mich., where the brines are especially rich in bromine. This plant is a most valuable future war asset of the United States, capable of yielding approximately 650,000 pounds of bromine per year. The tear gas which the Government prepared to manufacture was *brombenzyl cyanide,* a brownish, oily liquid which solidifies to white or brownish crystals at 29° C. Its production involves a fairly intricate chemical process. The first step is to chlorinate ordinary toluol, one of the coal tar bases, to produce benzyl chloride. This chloride is then mixed with sodium cyanide in alcoholic solution and distilled, benzyl cyanide being the result. It is then only necessary to brominate the benzyl cyanide by treating it with bromine vapor. Bromine gases are not poisonous in the sense of being killers, but are merely highly irritating to the membranes of the eye. The killing gases are phosgene, chlorpicrin, and chlorine. Mustard gas in sufficient amount is also fatal, its effect being identical to that of a deep burn. It attacks the lungs, the eyes, the skin, and even the intestines if food contaminated with mustard gas is swallowed. One of its insidious features is the fact that its action is practically always delayed. Goggles alone would usually be sufficient protection against tear gas, except for the fact that it is invariably mixed with the deadlier gases.

The production of gases and other chemicals was only part of the work of the Edgewood Arsenal and its subsidiary plants. The other chief activity was that of filling artillery shell with the toxic substances. The description of the plant which filled shell with phosgene will indicate the scale upon which this operation was conducted. The empty

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shell, after being inspected, were loaded on trucks, together with the proper number of loaded boosters. The booster was the device which exploded the shell and scattered the gas. Electric locomotives then pulled the shell trucks to the filling buildings. There were four of these to a single shell-filling plant, radiating at right angles from a common center. From the trucks the empty shell were lifted by hand to a belt conveyor and the conveyor carried the shell slowly through a room kept cold by artificial refrigeration. Although the shell moved only 70 feet through this room the conveyor traveled so slowly that they were 30 minutes in transit, and during this time they were cooled to a temperature of about 0° F. This chilling was necessary because phosgene has a low boiling point, and it was necessary to keep the temperature of the metal of the shell considerably below the boiling point of phosgene in order that the gas might remain in liquid form while the filling was going on. The chilled shell cases were next transferred to small trucks, each carrying six of them. The loaded truck was then drawn through a filling tunnel by means of a chain haul. This tunnel was so ingeniously contrived that the human assistance to the filling and closing machinery could all be conducted from the outside. The phosgene, kept liquid by refrigeration, was run into the shell by an automatic filler. The truck was then moved forward a few feet to a point where the boosters were inserted into the noses of the shell by the hands of the operator reaching in through an aperture in the tunnel. The final closing of the shell was then accomplished by motors. The air in the filling tunnel was constantly withdrawn by strong ventilation.

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the exhaust air being washed in stone towers by chemical agents to neutralize any gases that might be present. The filled, inclosed shell were next conveyed to a dump, where they were classified and then stood nose down for 24 hours to test them for leaks. Then they were painted, striped, and stenciled by air paint brushes. The final process was to pack them in boxes and store them for shipment. This was done in large storage magazines on the grounds of the Edgewood Arsenal. A similar method was used for filling shell with chlorpicrin, except that refrigeration was unnecessary.

Several filling plants were designed and constructed for filling grenades with stannic chloride and with white phosphorus, and for filling incendiary drop bombs. In this connection the table on page 26 is instructive:

The following is a summary of the production and expectations of the Edgewood Arsenal:

(1) The gas program as of March 1918, called for approximately 545 tons of toxic gas weekly.

(2) The Chemical Warfare Service program of August 12, 1918, called for a much larger amount, viz, about 4,525 tons per week.

(3) The approximate filling capacity of the Edgewood Arsenal plant from August to November, 1918, was nearly 1,000 tons per week.

(4) The toxic gas production during this same period increased from 450 to 675 tons per week.

(5) The capacity of all projectiles received, unlimited by boosters, varied during the same period from 125 to 450 tons per week.

(6) The maximum capacity corresponding to boosters received was less than 100 tons per week.

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The Chemical Warfare production organization developed and manufactured a large number of special containers for the shipment of toxic gases. These were of special construction in order to guard against dangers that would result from leaks, and all had to stand the tests required by the Bureau of Explosives before they would be received for rail-

SHELL, GRENADES, LIVENS DRUMS, AND DROP BOMBS FILLED

1918	75-mm. shell			Grenades		Livens drums	Incendiary drop bombs	
	Chlor-picrin	Phos-gene	Mus-tard oil	White phos-phorus	Tin tetra-chloride	Phos-gene	Mark I	Mark II
July	62,866	.....	.....	8,696	1,639	.....	.....	.....
August	125,951	.....	.....	170,160	56,763	1,738	350	.....
September	110,358	1,988	75,529	51,421	127,319	6,355	.....	1,998
October	109,704	12	79,272	110,928	147,669	12,026	184	100
November	15,892	9	224	98,948	30,386	5,570	8	6
Total	424,771	2,009	155,025	440,153	363,776	25,689	542	2,104
Total number shipped over-seas	300,000	.....	150,000	224,984	175,080	18,600	.....	.....

TOTAL MONTHLY CAPACITY OF FILLING PLANTS ON DATE OF ARMISTICE (STOKES SHELL, DROP BOMBS, AND OTHER SPECIAL CONTAINERS NOT INCLUDED)

75-mm. shell (ultimate capacity)	2,400,000
4.7-inch shell	450,000
155-mm. shell	540,000
6-inch shell	180,000
Gas grenades	750,000
Smoke grenades	480,000
Livens drums	30,000

road shipment. The 1-ton containers, all of which would hold 1 ton of liquid chlorine, were designed by the Ordnance Department and would withstand a pressure of 500 pounds per square inch. The 300-pound phosgene cylinders, designed by the Ordnance Department, were made to withstand a 500-pound hydrostatic pressure and a 250-pound air test.

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CHAPTER III

Gas Defense Equipment, the Problem of Gas Masks, Box Respirator Equipment, Canister Ingredients, Carbon (Charcoal) for American Canisters, Horse Mask Development, Production Data of Gas Defense.

During the spring and summer of 1917 two marked tendencies were to be observed in the fighting in France. One of these was the greatly increased use by both sides of poisonous gases and chemicals, frightful in their effect; the other the almost complete censorship that hid the knowledge of this tendency not only from the people of Europe but particularly from those of the newest belligerent, America. The French and British Governments, who then controlled all news from the front, feared, and perhaps with reason, that if the picture of gas warfare, as it was then developing, should be placed before the American people, it would result in an unreasonable dread of gases on the part of the American Nation and its soldiers.

The first masks adopted by the allies were simply gauze pads saturated with neutralizing chemicals. These became unsuitable as soon as new varieties of powerful poisons were brought out. The mask development thereafter progressed to the box respirator type. This consisted of a mask or helmet connected to a box filled with absorbing and neutralizing chemicals which purified the air for the mask

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wearer. This was the type of respirator in use to the end of the fighting. The first requisitions from the American Expeditionary Forces called for masks of two types, each soldier to be supplied with one of each. The reserve mask was to be of the gauze type and the regular mask of the box respirator type, affording protection from the more powerful poisons that were then just coming into use.

The box respirator equipment, the general principle of which was finally adopted by all the nations at war, fell into two classes. In a single-protection mask the wearer breathed air from inside of the face piece, so that any leakage around the edges of the face piece would result in a casualty when the wearer was in a strong concentration of gas. The other sort, known as the double-protection mask, consisted of a gas-tight face piece, similar to that of the single-protection mask. In this type, to guard against any possible leakage around the edges between the mask and the wearer's skin, the breathing system was sealed away from the air inside the face piece by means of a rubber mouthpiece and a nose clip, the wearer inhaling through the mouthpiece.

The United States and English double-protection masks consisted of 11 principal parts as follows:

1. A knapsack slung from the shoulder or neck. This contained the canister and a pocket for storing away the mask when not in use.

2. A metal canister in which was contained the absorptive neutralizing chemicals.

3. A flexible hose reaching from the canister to the face piece.

4. A flutter, or exhalation, valve, which opened when the wearer exhaled his breath and closed when

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he inhaled, thus bringing the inhalation through the canister but allowing the exhalation from the lungs to pass out without polluting the chemicals of the canister.

5. The face piece, or hood, fitting snugly around the edges and covering the eyes, cheeks, lower forehead, nose, mouth, and chin.

6. The eyepieces, or lenses, through which vision was maintained.

7. An elastic harness for the head, to hold the face piece in place.

8. A body cord to tie around the chest and hold the knapsack firmly, so that the mask could be seized in both hands and pulled out of the knapsack.

9. A metal flange connection or angle tube which carried the hose through the face piece to the mouthpiece.

10. A rubber mouthpiece through which the wearer breathed and which helped to hold the mask in place.

11. A wire nose spring and rubber nose pad to hold the nostrils shut and force breathing through the mouth.

It was necessary to overcome many difficulties in the production of an effective mask. In the first place, the face piece had to fit perfectly and not leak gas around the edges. It had to fit into the hollows of the temples and give the jaws a free space in which to work, and yet not slip back and press against one's Adam's apple. The pressure of the mask on the forehead must come above the supra-orbital nerves which are just above the eyebrows, or else intense headaches will result from a few moments' wear. Moreover, to fit all faces and

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heads, several graduated sizes of masks are required. The material of the face piece had to be gas-tight in itself. At first a fabric was made by spreading rubber on cotton sailcloth; and, after testing it, it was found that the smallest molecule known, that of hydrogen, would not pass through it in large amounts. This seemed to be a suitable fabric, until tested by the newer gases. Then it was found that some of these gases were soluble in rubber compounds and could dissolve their way through thin rubber so quickly that the face piece cloth offered practically no protection at all. Another difficulty with the rubber fabric was that it was likely to absorb and hold certain of the poisons, so that a man might be gassed by the mask itself. Experiment led to the discovery of a coating that would not only withstand gas concentrations for a sufficient time, but would also aërate promptly and lose as much gas as it had absorbed.

The eyepieces or lenses offered another problem. Celluloid is strong but it is not so transparent as glass. It ignites easily and is easily scratched. Glass is ideal in transparency and will not burn, but is fragile. Even so slight an accident as the breaking of a lens might cost a soldier his life by admitting concentrated gas to the mask. A material known as triplex glass was experimentally made. This consisted of a thin celluloid strip sandwiched between two layers of glass, all three welded together. This glass would not splinter, and even if cracked or broken, would still be gas-tight. However, this had never been made in quantity and it was necessary to work out many kinks and to start a large

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plant to provide the necessary millions of lenses. Then it was necessary to overcome the tendency of the eyepieces to dim, particularly in cold weather, as the wearer breathed moist breath into the mask. The answer to this problem was a soapy compound which put a slippery surface on the glass and avoided the droplets of mist. The first masks were also equipped with deep plaits so that the wearer could wipe off the lens with the interior of the face-piece itself, though the final development (the invention of a Frenchman by the name of Tissot) was to bring the cold air into the mask so that it flowed directly against the lenses and evaporated any condensed moisture. This kept them clear under all ordinary circumstances.

The metal tube passing through the face piece had to be free from pinholes and able to withstand rough handling without pulling loose. The harness had to maintain a gas-tight connection between the wearer's face and the face piece, but not at the cost of pain or chafing of the face or head. The flutter valve had to fit with absolute tightness and work perfectly and instantaneously at all times. The flexible hose leading from the canister to the face piece had to be strong and without flaws or leaks, and yet flexible in the extreme. A stiff hose would be likely to swing and displace the face piece whenever the wearer moved. The mouthpiece had to be comfortable and built along lines to prevent irritation to the gums or lips, yet reinforced so that in his excitement the soldier can not bite down and shut off his air supply. The canister had to withstand corrosion and be gas-tight. Smooth sided canisters could not be used, for the gas would slip up the sides

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without coming in contact with much of the chemical filling. The sides of the canisters were, therefore, ribbed so that the charcoal and other ingredients working into these ribs baffled the gas and threw it out into the body of the chemicals. The canister, moreover, had to be equipped with a perfectly working check valve which would stop exhalation through the canister and force the air to pass out through the flutter valve. The canisters were filled with charcoal and with cement granules. These were crushed into carefully sized small bits about the size of a pinhead and packed in layers in the canisters. The air could pass through them easily and the particles of both substances absorbed gas. The chief quality requirements for the carbon and the cement were that they must have long life and great activity. Of the canister ingredients the charcoal offered the more difficult technical problem.

During the winter of 1917-1918 the development of the mask continued and America designed her own typical mask—a gradual evolution, but one which, though based on the British design, arrived at a perfection which had been unknown in warfare before. The matter of rubberizing the face piece fabric was one of the most difficult problems to solve before proceeding in quantity production. Two methods of rubberizing cloth were in use. The first method was to roll out a thin sheet of rubber and then press it into the cloth fabric by running the whole thing under heavy rollers. This was known as the calender method. The other method, called the spreader method, was more intricate. In this process the sailcloth, tightly stretched, was carried around a roller. Above the roller a few thousandths

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of an inch was a knife blade extending from edge to edge. The rubber compound in liquid form was then fed upon the roller in such manner that a thin film of it pressed under the knife blade and upon the cloth on the roller. The rubberizing method finally adopted was a combination of the calender and spreader methods. The rubber was applied green to the cloth. The curing process thereafter was hightly important. If the curing process were too short, the rubber would be sticky and would pull off the sailcloth too easily. If the rubber were overcured, it would crack and split.

The story of the carbon (charcoal) which went into the American canister is one of the most interesting phases of the whole undertaking. Investigations carried on by the research staff of the National Carbon Company, aided by a clue from the University of Chicago, led to the selection of coconut shell as a raw material. Any carbon absorbs a definite number of times its weight of gas. Therefore the densest carbons will be most efficient, volume for volume, as gas absorbers in a given space. Coconut shells and other nut shells were found to be the most compact form in which carbon exists in nature in commercially practicable quantities, being considerably superior in this respect to anthracite coal and to such woods as ironwood and mahogany. Another essential for charcoal used in the canisters was that it must be so hard that it would not crumble easily and produce dust that would clog up the air passages and prevent easy breathing through the canister. Coconut shell fulfilled both of these conditions better than any other known material.

In further search for the ideal carbon experiments

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were made with almost every hard vegetable substance known. Next to coconut shells, the fruit pits, several common varieties of nuts abundant in the United States, and several tropical nuts, were found to make the best carbon. Pecan nuts, and all woods ranging in hardness from ironwood down to ordinary pine and fir, were found to be in the second class of efficiency. Among other substances tested were almonds, Arabian acorns, grape seeds, Brazil-nut husks, balsa, osage oranges, Chinese velvet beans, synthetic carbons, cocoa bean shells, coffee grounds, flint corn, corn cobs, cottonseed husks, peanut shells and oil shale. While many of these substances might have been used in an emergency, none of them would produce carbon as efficient, volume for volume, as that of the coconut shells and other hard nuts.

When we first began to build masks our demands for carboniferous material ranged from 40 to 50 tons a day of raw material; but by the end of the war, due to vastly increased mask requirements, we were in need of a supply of 400 tons of coconut shells per day. This demand would absorb the entire coconut production of the tropical Americas five times over. It was equal to one-tenth of the total coconut production of the Orient. Since transportation from the oriental countries was out of the question on the scale demanded by our mask program, it was evident that we were likely to be seriously embarrassed by the lack of raw materials; and, indeed, at no time before September, 1918, did we have on hand a reserve supply of shells and other charcoal materials that would last for more than a few days, though at no time after the start was the

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actual output of masks retarded by lack of these materials.

A great branch of activity in securing carbon supplies was undertaken in this country. In the search for fruit pits and for domestic nuts it was found that the quantity of apricot pits, peach pits, cherry pits (largely from the canning industry), and walnut shells on the Pacific coast amounted to 23,600 tons annually. The United States arranged for the whole Pacific coast supply of these commodities and converted a part of a San Francisco plant of the Pacific Gas & Electric Company into a plant for the preliminary carbonization of 100 tons a day of these materials. The next step was to turn to the consumers of the country and ask them to save their peach and apricot stones, their prune, plum, and olive pits, their date seeds, cherry pits, butternut shells, Brazil nut shells, and their walnut and hickory nut shells. The work of securing these and advertising the Government's need to the public was turned over to the American Red Cross. The Boy Scouts organized nut gathering parties. The Governor of Massachusetts proclaimed November 9, 1918, to be *gas mask day* for the collection of carbon material, and 28 other states fixed gas mask days in November.

The procurement of the nuts, however, was but the first step in the production of carbon for use in the mask canisters, for after charcoal is first burned its pores are still filled with various impurities which may be summed up by the word "tar." When the charcoal was given a second heating, under careful temperature regulation, this tar was burned out, with the result that the charcoal itself became much more active in its absorption of gas. In fact, prop-

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erly activated charcoal is more than absorptive—it is catalytic in its action toward the gaseous poisons used in the war, not only absorbing them but hastening their breakdown (digestion) into less injurious substances.

The activating of charcoal offered at the start considerably more of a problem than the question of making the charcoal itself, since activating had never before been conducted on a commercial scale. Two months of experimentation showed that the best distillation of shells and pits for charcoal was that conducted in illuminating-gas-making retorts. The activation thereafter had to be done in special equipment permitting of fine control of temperature. The Government eventually spent more than $1,000,000 in a charcoal activating plant, providing for America the best protection known to science against the poisons which Germany had introduced into warfare.

The cement granules, which also had to go into the canisters, supplied another problem. The basis of this cement was lime, to absorb gases of an acid nature. Portland cement was used, to give hardness and prevent disintegration and the formation of dust in the canister. Then infusorial earth was added, to make the compound porous in texture. A little sodium hydroxide was put in, to increase the alkalinity of the mixture. Finally there was an infusion of sodium permanganate, which is a powerful oxidizing agent. This latter chemical was added as a precaution against arsine. Arsine and arsenical compounds were difficult to use in warfare, but the Germans had introduced them to some extent, justifying the United States in adding this protection. In making the granules the sodium permanganate

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solution was mixed with the cement. The mixture was roughed out into slabs, allowed to set for three days, dried, ground up, screened to the proper size, and packed in drums for future use. The charcoal and cement were packed in the canister in alternate layers. The cement had the virtue of working while the carbon slept—that is, the carbon was active when there were gases present to be absorbed, but the cement kept on thereafter, digesting the gases which had been absorbed by the charcoal.

Early in 1918, shortly before the German drive commenced, there was brought out in France a single-protection mask, that is, a mask in which the inlet tube entered directly into the space between the mask and the face, with the orifices so arranged that the fresh air was drawn across the eyepieces. This was known as the Tissot mask. The principle of the Tissot was correct as far as comfort was concerned, since it did away with the irritating mouthpiece, but the chief danger in this mask arose from the fact that it was made of thin, pure gum rubber. The United States endeavored to produce a mask of this type which should be gas-tight and yet rugged. In this work hundreds of experiments were made to determine face and head sizes and shapes. It is interesting to note in this connection that the size of a man's face has nothing to do with the size of his head, as large heads with small faces and small heads with large faces occur not infrequently. Two developments of the mask without mouthpiece or nose clip were made. One was known as the Akron-Tissot, or Type A-T, and the other, an improvement in the design of the Tissot mask, called the Kops-Tissot, or the Type K-T. In exact figures,

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up to the time of signing the armistice there was a total production of 5,692,499 masks of all types.

Hand in hand with this procurement and manufacturing achievement went the development of the technical section of the Gas Defense Division. In spite of this elaborate section, the testing of masks did not stop with it. There was a special field-testing section of the Gas Defense Division, composed of about 150 men who were trained to the minute in field maneuvers and did most of their work in gas masks. They were constantly in and out of gas with regular production and experimental masks, they played baseball in them, they dug trenches, laid out wire, cut wire, and fought sham battles at night, both with and without actual gas. The work of this section even went so far in the case of the later designs as to include a test where six men worked, played, and slept in the masks for an entire week, only taking them off for 30 minutes at each mealtime, and each day entering high concentrations of the most deadly gases, without any ill effects whatsoever to the wearers. When it is remembered that eight hours was the limit of time which a strong man could wear the old-type mask, something of the efficiency of the new mask may be realized.

Investigation showed that a horse's eyes did not shed tears in the presence of even strong lachrymatory gases. Moreover a horse never breathes through his mouth; and it was, therefore, necessary only to cover his nostrils. Furthermore, horses proved to be more resistant to the toxic gases used in Europe than were men, and his mask, accordingly, needed to be only a bag of many layers of chemically treated gauze. The following table is most inter-

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esting and shows the number of respirators, canisters, horse masks, bleaching powder (tons), antidimming (tubes), sag paste (tons), dugout blanket oil (gallons), protective suits, protective gloves, dugout blankets, warming devices, and trench fans manufactured during the European War. The dugout blankets were to be used at the doors of dugouts to make them gas proof. These were specially woven all-cotton blankets which were treated in France with a special heavy oil, shipped from the United

Item	Production		
	Up to July 1, 1918	Up to Nov. 11, 1918	Dec. 31, 1918 (total production)
Respirators	1,719,424	5,276,515	5,692,499
Extra canisters	507,663	3,144,485	3,189,357
Horse masks	154,094	366,529	377,881
Bleaching powder (tons)	1,484	3,677	3,590
Extra antidimming (tubes)	.....	2,855,776	2,855,776
Sag paste (tons)	20	1,136	1,246
Dugout blanket oil (gallons)	.....	95,000	95,000
Protective suits	.....	500	2,450
Protective gloves	.....	1,773	1,773
Dugout blankets	.....	159,127	191,338
Warning devices	.....	33,202	45,906
Trench fans	11,343	29,977	50,549

States. The protective suits and gloves were to safeguard men against mustard gas burns. The suits were made of oiled fabric and the gloves were of cloth impregnated with chemicals. The ointment known as sag paste was used to protect the skin against mustard gas burns. The gas warning signals were of several types, watchmen's rattles and Klaxon horns being the most commonly used to sound the gas alarms. The trench fans were used for fanning out gas from trenches and dugouts.

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CHAPTER IV

Tactical Employment of Gases, Importance of Gas as a Weapon in Military Operations. Lachrymators or Tear Producers, Density of Gases and Time of Exposure, Gases from Shells, Artillery Gas Zones of Dispersion, Effects of Temperature and Terrain.

The introduction and development of the use of gas in military operations has had a marked effect on the action and employment of troops in combat. A proper tactical training now requires careful instruction not only in measures of defense against gas, but in the use of gas against the enemy in offensive and defensive operations. Beginning in April, 1915, with the first successful use of gas in the form of a gas cloud projected from cylinders the forms and methods of use have been extended to include the use of the usual arms of combatant troops in the projection of gas and the employment of special arms for its projection.

The general term "gas" as now used in warfare embraces all poisonous gases used in war, whether in cylinders, shells, or otherwise, and in addition, smoke, incendiary and irritating substances. The chemical substances designated as "gases" have a great variety of properties and effects. To think of all "gases" as having substantially the same properties and tactical uses is a serious mistake. The "gases" used in warfare include not only true gases, but solids and liquids of widely varying properties,

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that are converted in their actual use into "particulate" gases and vapors. This makes possible a wide variety of tactical uses in combination with other means of warfare. The effect of gas persists after the explosion, imposing upon the enemy the necessity of wearing masks. This is a source of discomfort and impairment of vision and efficiency. Gas is, moreover, capable of penetrating certain means of defense, such as trenches and dugouts, sometimes more effectively than other forms of ammunition.

In order to realize the value of the employment of gas in military operations and the need of the measures of defense against gas, as well as to determine the conditions under which the use of gas is applicable, a knowledge of the physical properties and the physiological effects of gases and their behavior upon release, is essential.

The most important physical property is that which determines the "persistency" of the substance when used in the field. This property depends chiefly upon the rapidity of evaporation, which may be roughly estimated from the boiling point of the liquid. According to this criterion, we may name the following classes, giving the most prominent example of each:

GROUP I—Substances which are gases at ordinary temperatures (of low persistency)—Phosgene.

GROUP II—Moderately volatile liquids (of moderate persistency)—Chlorpicrin.

GROUP III—Slightly volatile liquids (of high persistency)—Mustard Gas.

GROUP IV—Toxic smoke producers—Diphenylchlorarsine.

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Gases at ordinary temperatures (like phosgene), when released from containers, will be blown about by the air currents; hence, if the air is relatively still, as when the wind is low, or in a dense wood, such a gas may persist for some time. On the other hand, in the open, and when the wind is blowing, it will be quickly dissipated. Such a gas can be used advantageously against positions to be attacked shortly after the release of the gas.

Moderately volatile liquids (like chlorpicrin), when splashed upon the ground, will vaporize rather slowly, and will continue to contaminate the air in the neighborhood. In woods or in dugouts, or when the air is still, this contamination may persist for considerable lengths of time. However, that portion of the liquid which has vaporized is no more persistent than the gases in the phosgene group.

The slightly volatile liquids (like mustard gas) will give off their vapors still more slowly, so that an infected area will remain dangerously infected for a greater length of time. However, it is difficult to get their vapors into the air in high concentrations. Only by breaking them up to form a mist can high concentrations and rapid deadly effects be realized. Substances of this class are accordingly especially useful in harassing an enemy and in preventing him from attacking over areas drenched with them. It has, in fact, been possible to ascertain positions which the enemy expected to attack by noting gaps left in territory otherwise heavily shelled with mustard gas.

Toxic smoke producers (like diphenylchlorarsine) are substances which can be made to give a suspension of extremely fine particles of poisonous

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dust, or mists in the air. Such clouds are no more persistent than those caused by gases in the phosgene group. Their chief value lies in their ability to penetrate, more or less, the enemy masks. Usually when the cloud has settled upon the ground the amount of vapor given off is too small to have any toxic effect. Such effect is only produced by the inhalation of the particles themselves while suspended in the air.

The toxic substances may be classified according to the predominant effects which they exert, with the understanding, however, that the action of any substance is not limited to a single tissue or group of tissues. Thus, a substance, the vapor of which causes injury to the respiratory passages, may, when applied to the skin, cause blistering. If the sole or chief usefulness of a substance in warfare depends upon its effect on the respiratory tract, it is classed as a respiratory irritant. If its power to produce casualties is due to its action on the skin, it is classed as a skin irritant. If both actions are useful, it is placed in both groups. By far the greatest number of substances thus far used injure the respiratory apparatus. Three groups may be differentiated:

(a) Those which exert their chief effects upon the delicate membranes in the lungs through which oxygen passes from the air into the blood. The main result of this injury is to cause fluid to pass from the blood into the minute air sacs and thus to obstruct the oxygen supply to the blood. Death from one of these substances may be compared to

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death by drowning; the water in which the victim drowns being drawn into his lungs from his own blood vessels. Examples: Phosgene, chlorine, chlorpicrin, diphosgene.

(b) Substances which injure the membranes which line the air passages. During normal life these membranes insure protection to the lungs against mechanical injury by particles which may be taken in with the air and against bacterial infection. As a result of the action of substances of this group their protective power is lost. Portions of the membrane may become swollen and detached and may plug up the smaller passages leading to the lung tissue, or the damaged tissue may become the seat of bacterial infection, thus setting up bronchitis and pneumonia. Examples: Mustard gas, ethyldichlorarsine.

(c) Substances which affect chiefly the upper air passages, i.e., the nose and throat. These substances cause intense pain and discomfort but are not dangerous to life. They cause sneezing, painful smarting of the nose and throat, intense headache, a feeling of severe constriction of the chest, and vomiting. For varying periods after exposure they may cause general muscular weakness and dizziness, loss of sensation in parts of the body or even transitory unconsciousness. Examples: Diphenylchlorarsine, diphenylcyanarsine.

Tear Producers (lachrymators).—Certain substances have a powerful effect upon the eyes, causing copious flowing of tears, followed by reddening

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and swelling of the eyes, producing thereby effective temporary blindness. These effects are often produced by extremely minute quantities of tear producing substances. Larger quantities of the same substances usually act as lung irritants as well. Examples: Brombenzylcyanide, bromacetone, ethyl idioacetate, chlorpicrin.

Skin Blisterers (vesicants).—Certain substances have a powerful irritating effect upon the skin, very much like that produced by poison ivy. The same effect is produced upon all the surfaces of the body with which the substance may come in contact, such as the eyes and the breathing passages. Accordingly, a substance producing skin blistering will, if inhaled, also act as a powerful irritant of the air passages. Example: Mustard gas.

The following table includes the most important substances in use in Chemical Warfare, grouped according to persistency, with brief indications of their physiological effects. Little attempt is made to describe the odors, as this is very difficult. However, all who have any responsibility in connection with Chemical Warfare, should become familiar with the various odors by actual experience:

NAME	PROPERTIES	
	Physical	*Physiological*
GROUP I—*Gases at Ordinary Temperatures.* (Readily dissipated by wind. Non-persistent.)		
Chlorine (Bertholite)	Greenish Yellow Gas.	Lung irritant, death rapid or delayed. Less toxic than phosgene. Odor like that of bleaching lime.

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NAME	PROPERTIES	
	Physical	*Physiological*
GROUP I—*Gases at Ordinary Temperatures.* (Readily dissipated by wind. Non-persistent.) —*Continued.*		
Phosgene (C. G.) (Collongite)	Colorless gas, easily liquefied.	Lung irritant, death rapid or delayed. Mouldy odor.
Hydrocyanic Acid (V. N.) (Vincennite)	Colorless gas, easily liquefied.	Nerve poison, immediate death if concentrated; very little effect if dilute. Rapid recovery with no after effects.
GROUP II—*Moderately Volatile Liquids.* (Moderately persistent.)		
Chlorpicrin (P. S.)	Liquid less volatile than water.	Lung irritant, slightly less toxic than phosgene. Tear producer.
Diphosgene (S. P.) (Superpalite) (Green Cross)	Liquid less volatile than water.	Lung irritant.
Dichlorethylarsine (Yellow Cross 1) (New Green Cross 3)	Moderately volatile liquid.	Nerve poison and respiratory irritant. Produces pain in throat, chest and head.
GROUP III—*Slightly Volatile Liquids.* (Highly persistent.)		
Brombensylcyanide (C. A.). (Other tear producers similar in properties and effect.)		Powerful tear producer.
Mustard gas (H. S.) (Yperite) Dichlorethylsulphide. Yellow Cross	Liquid, boiling at 217° C. (423° F.) Faint pungent odor when pure. Garlic odor from shell bursts.	Air passage irritant, producing death, and skin blistering agent. Eyes and genital very sensitive. Effects often delayed 3 hours to 2 days.
GROUP IV—*Toxic Smoke Producers.*		
Diphenylchlorarsine (D. A.) Sternite, (Blue Cross).	Solid, melting at 39° C. (102° F.), boiling at 333° C. (632° F.) vapor condensing to smoke.	Produces violent pain in head, throat and chest, with sneezing and coughing.
Diphenylcyanarsine.	Similar to diphenylchlorarsine.	Same effects as D. A., but more powerful.
Stannic chloride (K. J.)	Volatile liquid forming solid smoke with moisture of the air.	Little toxic. Gives opaque cloud and penetrates German mask, producing coughing.

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The degree of the physiological effects stated above depends on the time of exposure and the density of the gas. It is evident that the more dilute the gas, the greater is the time of exposure necessary to produce an equally toxic effect. We may say roughly that doubling the concentration of a given gas reduces the time of exposure necessary to kill by at least half, and usually by more than half. This is very important in connection with tactical considerations, because the chief effectiveness of the gases of the non-persistent type, like phosgene, is attained through surprise-poisoning the enemy before he is able to put on his mask. It is exceedingly important, from this standpoint, to surround him suddenly with gas of sufficient concentration before his mask is in place.

The effectiveness of mustard gas is partly due to the fact that it retains its proportionate effectiveness at very low concentrations. The low concentration of one part in 100,000 acting for 20 minutes produces as much effect as the high concentration of one part in 10,000 acting for 2 minutes. This is also true to a large extent with chlorpicrin. On the other hand, the toxicity of hydrocyanic acid (the toxic constituent of Vincennite), falls off much more abruptly as the concentration diminishes, so that a dilution is very soon reached at which it can be breathed almost indefinitely with no bad results.

When gas is liberated from a cylinder it is blown along the wind and as a result of the eddies set up by its passage over the surface of the ground, it is

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mixed with air. The height of the cloud, when the ground is cool and the wind is not too high, is not very great, being limited largely by the height to which the eddies extend. Over smooth ground this amounts roughly to 30 feet at a distance of 100 yards from the point of emission, increasing only slowly at greater distances. The cloud spreads laterally in the form of a fan. The angle of this spread may vary from 15 to 25 degrees. It is safe to take 20 degrees as an average. This means that the width of the cloud at any distance from the cylinder will be about 0.4 of the distance. An increase in this angle seems to be favored by decreases in wind velocity and by increase in the rate of emission of the gas. It is possible for practical purposes, to calculate the concentration of gas in the cloud at varying distances from the cylinder provided the velocity of the wind and the rate of emission of gas are known. The concentration will be greatest in the middle, decreasing toward the edges. Increased wind velocity produces a proportionate decrease in the concentration of the cloud. The average concentration at any cross section of the cloud falls off somewhat more rapidly than the increase of the distance from the cylinder. Thus, if the concentration were one per cent at 50 yards, it would be somewhat less than 0.5 per cent at 100 yards, and considerably less than 0.05 per cent at a thousand yards. If gas is emitted from the cylinders or groups of cylinders at a distance from each

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other, each cloud will behave as above, but at the point where they begin to intersect dilution will become very slow.

As the clouds formed from bursting gas shells proceed down the wind, the rate of speed is roughly the same as for the fan shaped cylinder discharge. Viewed from the side in elevation, these clouds are seen to spread out to a very great extent in the direction of travel. This is due to the friction offered by the ground to the passage of the wind, that portion of the gas cloud closer to the ground being retarded the most. This longitudinal spreading of the cloud from a single shell burst causes it to dilute much more rapidly, as it proceeds from the point of emission, than does the cloud from a cylinder discharge. Of course, the retarding influence of the ground operates in both cases, but the continuous supply of gas from the cylinder tends to keep up the concentration. The result of artillery fire is usually a succession of distinct clouds, due to limitations in the rapidity of fire and to the dispersion of the shots. It is very important, therefore, that bursts should be as close as possible to windward of the target, in order to surround the target with clouds of the maximum concentration. Just as the behavior of the cloud from a single cyinder discharge enables one to predict the general behavior of the cloud formed by the simultaneous discharge of a number of cylinders, so the behavior of the cloud from a single shell burst, as outlined above,

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allows the prediction of the effect of gas shell fire in relation to wind, rates of fire and zones of dispersion.

When the gas shells are fired at a position the shells do not burst simultaneously. The zone of dispersion of a gun is the pattern produced upon the ground by the impact of a large number of shells from a single piece. This pattern is independent of the rate of fire. The individual gas clouds move at once with the wind from the points of burst, each growing and diluting. If, as is usually the case, the shells do not fall simultaneously the effective zone of dispersion becomes not a pattern on the ground but a pattern in the air elongated in the direction of the wind. This elongation has the effect of an increased dispersion, the increase being greater the greater the velocity of the wind and the less the rate of fire. Doubling the rate of fire will distribute the gas in roughly half the area, producing thereby at least twice the concentration and having far more than twice the effect in producing casualties. It is evident, also, that an increase in the wind velocity will distribute the gas over a larger area, decreasing the concentration of the cloud.

One of the chief reasons for the *effectiveness of gas* is the fact that the cloud of gas is present for an appreciable length of time after its emission from cylinder or shell and is capable of producing casualties until the division becomes too great, or until it is blown away. Increased wind velocity reduces rapidly the length of time that gas remains in the

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neighborhood. Gas is used most effectively in winds under 3 meters per second. However, too low a velocity is objectionable in the case of gas emitted near our own lines because of the possibility of a variation in wind direction bringing the gas back. Gas may be used in artillery shell fire at longer ranges even when the enemy is to windward by so adjusting the amount of gas used that the concentration will be harmless when it reaches our own lines.

In order to kill a man with gas by surprise, it is necessary to surround him with gas so concentrated that the small amount he must breathe before getting his mask on is effective. After his mask is put on, the gas cloud is of relatively small effectiveness. Even when the enemy is wearing his mask, however, it is desirable to subject him to gas of high enough concentration to penerate the mask, especially the nearly exhausted ones likely to be in possession of many of the enemy's troops.

When the ground is considerably warmer than the air, as when the sun is shining brightly, vertical currents of air rising from the surface of the ground are generally produced, which have a great tendency to dissipate gas clouds. For this reason, gas is used far more effectively at night, or when the sky is overcast.

It is very difficult to obtain a gas cloud, containing more than 0.1 per cent. of gas, for more than a very short time after its release, and even this concentration rapidly diminishes. Therefore, there is

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but little difference in physical behavior between a so-called gas cloud and so much air. Its density is but infinitesimally greater, and it is subject to the same movements as the surrounding air. If it stays longer in a valley than on higher ground it is chiefly because the winds blowing at higher elevations are not so strong in the valley.

Features of terrain which affect the movement of the air affect the movement of gas clouds in almost the same way. Tall grass, bushes, trees, buildings, etc., retard the movement of air, and in an increasing degree they retard the movement of and retain gas clouds. In an attack following a gas bombardment, more time must be allowed if a field of grain is in the path than if short grass or ploughed fields intervene. Still more time is, of course, necessary where bushes or trees are present.

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CHAPTER V

Tactical Use of Artillery Chemical Shell, Smoke Screens and Smoke Shell, Handling and Storage of Gas Shell, Transport and Storage of Gas Shell, Gas Shell Dumps and Batteries.

The employment of gas is greatly influenced by earth forms, wooded and undulating ground having a very great influence on the result of a gas shell bombardment. The effect of topography is closely connected with atmospheric conditions, which it influences by altering the direction and force of air currents. Gases, being slightly heavier than air, tend to flow into gullies, draws and valleys, leaving the tops of hills free. In deep, narrow and long valleys, currents of air are usually found which carry the gas long distances.

In hilly country special attention must be paid to deviations of the lethal wind from the general air current and to the mountain winds which in clear weather set in at certain periods of the day. A drifting of the gases from higher to lower places, such as obtains with attacks with gas projectors, cannot be reckoned with, for the gas density in the air is less in bombardments than in the spraying method.

Gas may be used under intelligent direction in

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nearly every character of terrain. It may be most satisfactorily used in almost level, slightly undulating districts.

Targets, such as woods, may be shelled with good results when the wind has too high velocity for targets situated in open ground. When undulations in the ground are very marked, the fact that the wind is stronger on high ground than on low must be taken into account. High ground and open places must, therefore, receive a more intense concentration than those localities which are wooded or enclosed.

During gas shell bombardments in open country, particular attention must be paid to the deviation of the local wind from the general wind direction and to air currents peculiar to the combined action of mountains and valleys, which occur on certain days in bright weather. That is, you must, if possible, consider what the wind conditions are at the enemy position.

With the long range of artillery, gas may be safely sent over to the enemy no matter what the direction of the wind. It is merely necessary to establish safety zones, and knowing the characteristics of the gases available, deliver the gas where it may be needed in an effective dose, which at the same time cannot be blown back in dangerous quantities to our own line. To do this requires the ability to make use of topographic maps and judge the effect of topography on prevailing winds. The Gas Officer cannot do good work without good topographic maps. On each map which exhibits the

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trench systems, he should mark the Gas Safety Zones and draw a wind circle six inches in diameter. This wind circle is divided into forty parts, called "Grads," numbered clockwise.

The daily meteorological report gives the direction of the wind by numbers. The wind blows from the circumference to the center of the circle, which represents the gun position. The 0 of the circle is north, 10 is east, 20 is south and 30 is west. In transmitting wind data, 50 is added to wind speeds to prevent confusion with the numbers which indicate wind direction. The speed is in meters per second. The artilleryman uses the wind circle to make meteorological corrections to his firing data. The Gas Officer uses the wind circle to study the probable effect of typography on the travel of a gas cloud impelled by the prevailing wind. The wind direction should be plotted on the maps.

The Gas Officer should lay over his map each day a piece of transparent paper. On this he should trace the boundaries of the safety zone, a few of the heavier contours showing marked earth forms and also the bottom of all large depressions and the crests of all hills, indicating heights by figures. Across the hills and valleys he should draw in yellow pencil parallel lines indicating the wind direction. Mark in figures on these lines the speed in meters per second. Date each sheet and sign it. With the data thus ready, the Gas Officer can quickly decide just what gas to use on a certain target and the quantity. These sheets should be filed for record

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and the one used on the day on which gas is fired should accompany the report on the firing, a copy being retained at headquarters.

In order to be able to allow for unexpected atmospheric changes, the firing order should, if necessary, be given by pre-arranged signal visible at great distance; for instance, from a captive balloon. A similar signal is also to be decided upon in case break or cessation of the bombardment is necessary. The lighter the bombardments are, the more can these measures be modified.

Two general types of bombardment with gas shell may be carried out. Variations and combinations of these two types should be often employed. The two general types are:

Destruction Fire.—This type of bombardment is to be carried on with lethal shell, and is intended to produce casualties. Ordinarily, firing for more than two minutes at one time is not profitable, though in dead calm or thick woods and similar places, especially at night, the time may be extended to five minutes. Too much emphasis cannot be laid upon the fact that a gas attack must be executed with the greatest rapidity of fire and that the hits be close together, so as to create a solid gas cloud. Only in complete absence of wind may the rapidity of fire be decreased. In case of air currents, allowance must be made accordingly in the range finding. Gas effects at the objective must be obtained quickly. The necessary number of rounds is therefore to be distributed to as many batteries as possible.

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Neutralizing Fire.—This fire is intended to lower the physical resistance, morale of the enemy, and to interfere with his activities, by causing him to wear his mask continuously, for a considerable time. This result can be obtained most economically with persistent gases.

Heavy fire, or a very rapid rate of fire, with a persistent gas is not necessary. Since instantaneous lethal effects are not obtainable, a heavy burst of fire at the commencement of a bombardment is not required. After the desired concentration has been reached, it is only necessary to fire a small number of shell occasionally in order that this concentration will be maintained. A sudden burst of fire with mustard gas amounting to 1/10 that for phosgene may be used to begin a bombardment.

Counter-Battery.—This, as a rule, should consist of a burst of destruction fire, followed by a slow, neutralizing fire with a persistent gas. The final burst of concentrated fire with a lethal gas is often useful, if the neutralizing fire has been maintained for four or more hours. This final burst of fire should last for ten or fifteen minutes. Its purpose is to penetrate the enemy masks that have been exhausted by long continued wearing.

Harassing.—This is solely a neutralizing fire, for the purpose of hampering enemy movements of material, and troops, and to cause exhaustion of personnel through wearing the mask. Lachrymatory gases are used primarily for harassing effect. Any lethal effect obtained from those gases will be purely

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incidental, and they should not be used for this purpose, as the amount required would be abnormal. Where lethal effect is desired after lachrymatory firing, a bombardment with lethal shell may follow immediately.

Blanketing.—This is a type of neutralizing fire which may be employed under especially favorable weather conditions. During a dead calm (at night) it is possible, with a comparatively small number of shell, to form clouds of gas which will lie in pools of fog, in hollows and valleys, for a considerable time after the shelling has ceased. If no wind arises, the enemy will have to wear his mask all night, or vacate the low ground. Non-persistent, lethal gases are useful in such cases. *Caution*: The objective must be far enough away from the friendly line to avoid danger from a slight drift of the clouds or from an adverse wind springing up.

Interdiction Fire.—This is a type of neutralizing fire for the purpose of rendering important positions untenable. This is best carried out by the use of mustard gas, unless our troops expect to occupy or pass over the area soon after the bombardment.

Bombardment of Area.—In the bombardment of an area, which is essentially a question of neutralizing fire, it should be noted that it is often advisable to open the fire with a burst of lethal shell on certain important targets in the area, and then to carry out the slow neutralizing fire.

While attacking one front, a harassing and neu-

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tralizing mustard gas bombardment can be effectively made on fronts, flanks, rear areas, and strong points not thus attacked. Troop concentrations, reserves, artillery groups, lines of communication, villages, and extended areas which it is contemplated the advancing troops will not reach, may be attacked with mustard gas.

When more than one objective is to be attacked for surprise effect with a lethal gas, the objective to the leeward of the wind is to be bombarded first. In this way the surprise effect on the second objective is not lost. However, if fire on other targets is made soon enough so the wind will not carry gas to later targets before fire is opened on them this rule need not be applied.

When harassing fire with a tear gas is to be used upon more than one objective, the objective to the windward should be first bombarded. When it is not considered practicable to attack a strong position by frontal assault the position may be rendered untenable for the enemy by shelling heavily with mustard gas, which will not interfere with surrounding or passing around the position.

Barrages.—Gas shell may be employed in a barrage, in the following ways:

(a) Accompanied by high explosives, under favorable weather conditions, gas tends to cause confusion among the enemy. About 25% of gas shell (1 gun per battery) should be used. While no danger to our own troops will occur from the use of this small percentage of gas shell, it will serve

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to deceive the enemy, causing him to wear his mask, and in this way hinder his activity. With a four mile per hour wind, men can follow within one minute.

(b) May be used in "back" barrages, during an attack, to place enemy reserves and reinforcing troops at a disadvantage, by compelling them to wear masks. This is highly destructive to morale.

Smoke screens have many times greatly aided in the execution of all sorts of operations, large and small, and it would seem that their use should be greatly extended. Smoke candles or grenades will always be used for the production of smoke, when their use is possible. Within the limit of their range trench mortars should be used. At greater distances artillery shell are a necessity. For all uses of smoke clouds, wind conditions must be carefully studied.

There are two varieties of smoke shell in our service: White phosphorous (W. P.) shell, used only for screening purposes, and titanium tetrachloride (F. M.) shell, used only for ranging purposes. The W. P. shell are not intended for ranging, but they can be used for this purpose when the F. M. shell is not available, provided certain corrections are made. Vice versa, the F. M. shell are not intended for screening purposes, although they may be used as such, if W. P. shell are not available. The F. M. shell will not give as dense and durable a cloud of smoke or as great a screening effect as the same size W. P. shell, hence it will be necessary to increase the number of F. M. shell used and the

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rate of fire over the figures prescribed for establishing smoke screens with W. P. shell.

Smoke may be used by the artillery (1) to blind enemy observation posts, machine gun emplacements, infantry or artillery, thereby screening-in infantry raids or other operations. (2) In order to draw fire and distract attention from another operation. (3) To define the visibility limits of an attack or raid. (4) As a fake gas attack, or to make the enemy think a real gas attack is more extended. (5) In back areas to screen gun positions, etc. (6) Occasionally for burning effect against enemy troops.

The number of smoke shell required to form an effective screen depends upon the considerations above enumerated. In winds much over 20 miles per hour it is practically impossible to form an opaque screen. The stronger the wind the further must be the source of the screen from the objective. Experiments have shown, however, that a screen can be formed even in a strong wind. The best wind for the use of artillery shell appears to be one having a velocity of about 14 miles per hour (6 meters per second), and blowing across the object to be concealed.

One hundred yards per 10 feet per second of wind may be taken as a general guide as to the distance from the object at which artillery smoke shell should be placed. In hot weather particularly the smoke tends to rise from the ground, and there is, therefore, a greater tendency for gaps to form in the screen.

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The effect of phosphorous shell of all kinds is cumulative, as the globules of phosphorus continue to burn on the ground from 15 to 20 minutes. As the cloud in the case of phosphorous projectiles is at its thickest soon after the bursts, it will be maintained more evenly by adding small quantities at frequent intervals of time rather than by adding large quantities at greater intervals.

No definite rules can be laid down as to the exact quantities of smoke shell required to form a screen, as the conditions will vary to a very large extent. However, as a general guide it may be taken that the following number of shell are required to form an adequate smoke screen under normal conditions:

75 mm. shell, 2 rounds per 10 Yds. per Minute.
4.7-inch shell, 2 rounds per 15 Yds. per Minute.
155 mm. shell, 2 rounds per 25 Yds. per Minute.

The above figures apply to the establishment of the smoke screen which may thereafter be maintained by a reduced rate of fire, which should be controlled primarily by observing the behavior of the smoke screen. In general, it may be stated that one half the above rate of fire will effectively maintain a smoke screen after it is once established and under normal conditions.

The chief source of danger in handling gas shell is leakage, which can always be detected by the smell, or by the effect produced upon the eyes. All personnel handling these shell should carry gas masks. The handling of shell under suspicion, and the res-

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cue of any man affected by the fumes will be the duty of special detachments which should be detailed and trained for this purpose. If a leak is suspected, it should be reported immediately and all men working in the vicinity should bring the respirator to the "alert" position.

Leaking gas shell may be disposed of by burying them and by exploding them.

Shell should be buried six feet deep and covered with a layer of chloride of lime before filling in the earth. They should not be fired from the gun. Spots where defective shell are buried should be indicated by sign posts driven into the ground and marked in an appropriate manner. Leaky shell can generally be detected by the smell of the gas.

If there are large numbers of leaking shell, it is more satisfactory to explode them than to bury them, thus preventing the contamination of the area from a large number of buried shell. When gas projectiles are to be blown up, they should be collected in lots so as not to exceed 100 lbs. of gas. Each lot should be exploded singly and another lot should not be exploded until the first gas cloud formed has disappeared. The gas cloud from one lot of this size is dangerous up to 500 yards' distance, and personnel within that distance to leeward should be warned. The procedure for exploding the gas projectiles is almost the same as that followed for exploding H. E. and shrapnel. The projectiles are piled in a narrow ditch about 6 feet deep, and an explosive or blasting charge is placed in the center of

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the lot and connected up to the blasting loads or time fuse. The lot is then covered with sand bags or other material to keep the metal pieces from scattering. The lot is then exploded. Then when the gas cloud has fairly well cleared, men wearing the respirators will fill in the holes, first covering with a layer of chloride of lime. Men working at destroying the blind gas projectiles should always wear the respirator from the moment they start to blast. Under no conditions should leaking shell be thrown into water. The necessity of careful handling of this sort of ammunition cannot be impressed too strongly.

Wagons containing gas shell, on arrival at depots, will be opened by a gas non-commissioned officer, who will supervise the unloading and storage of shell. If the presence of a leaking shell is suspected in any wagon, the matter must be reported at once to the officer in charge. Such a wagon will then be unloaded by a special detachment wearing the respirator in the alert position. If possible, gas ammunition should be carried in trucks provided with shutters which should be left open. If closed trucks only are available, on arrival at the ammunition depot, or dump, the doors of both sides should be opened by a competent person and no one should be allowed to enter the truck until it is ascertained whether or not any gas has leaked. If, of necessity, open trucks have to be used, no tarpaulins should be put on.

This ammunition should be stored in separate

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bays and should be ventilated as well as possible, compatible with the exclusion of rain. If stored under tarpaulins, arrangements should be made to give access of air to the stack. Gas shell should be left in a cool place, as heat increases the internal pressure and the possibility of leaks.

Buildings on or about the line between the gas area of the ammunition depot and the direction of the wind, must not be occupied during a raid. A messenger wearing a box respirator should be sent off to rouse sleeping men in such buildings and to see that the buildings are clear. If gas ammunition has been destroyed, it is forbidden to enter these buildings until they have been ventilated thoroughly, by men wearing respirators. All windows and doors of the building may be opened and wood fires burned in the center of the cellars. The building will be occupied only when declared safe by a gas officer or gas non-commissioned officer.

At battery positions, gas shell should be piled in small dumps, the number in each being generally limited as follows:

The 75 mm	100
The 4.7-inch	50
The 155 mm	25

Dumps should preferably be located to the leeward of battery positions, according to the prevailing wind. If a direct hit occurs on a dump of gas shell, respirators will be put on immediately and without waiting for orders, and if possible a move

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will be made to the windward. All personnel of a battery will be kept constantly informed of the direction of the wind. "Dud" gas shell, or gas shell débris, must not be touched until examined by a gas non-commissioned officer, who will attend to the proper disposal of the same.

Mustard gas shell which show traces of leakage should be handled only by men who are protected with respirators and special gloves. Men detailed for such work should likewise be equipped with protective clothing (if obtainable), whenever there is a possibility of the projectiles coming in contact with the clothes.

As soon as the shell are received, they should be examined. Any indication of leakage at the gaine joint is a danger sign. (Masks and gloves should be worn.) Whenever possible, cases containing the shell should be stored in small piles in the open air. Near all such piles, a heap of earth and a supply of chloride of lime should be provided for covering any shell that may be burst by enemy fire. All storage depots should be supplied with shovels, and with chloride of lime in air-tight containers.

If a mustard gas shell dump is reached by enemy fire, all personnel should move off to the windward and all men within 200 meters to the leeward should be warned. Broken shell should be covered with a layer of chloride of lime on top of which 6 inches of earth should be spread. During this work, masks and protective gloves should be worn. Undamaged shell of a small dump struck by a direct hit will not

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be set apart for future use, but will be buried with the fragments of the damaged shell in a hole six feet deep and covered with a layer of chloride of lime before filling in.

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CHAPTER VI

Chemical Artillery Ammunition, Construction of Gas Shell, Types of American Shell, Smoke Shell, Incendiary Shell and Fuses, Fillings for Gun and Howitzer Shell.

Gases for use in artillery shell are divided into three classes—non-persistent, semi-persistent, and persistent. The *non-persistent* gas, known as C. G., is most commonly used. It boils at +8°C. (46°F.) and is lethal. In general, the non-persistent gases all have the same characteristics. They are all lethal and boil below +20°C. (68°F.) i. e., below normal atmospheric summer temperature. For this reason these gases change from liquids to gases without the aid of any artificial agency. When the shell is burst the liquid at once gasifies. Hence, the smallest bursting charge that will effectively open the shell is used. However, the bursting charge must be of sufficient strength not only to burst the shell, but also to check, to a large extent, the forward velocity of the base portion of the shell. Otherwise a considerable portion of the liquid will be cupped in the base portion of the shell and buried in the ground or carried by ricochet beyond the point of burst.

In the employment of lethal gases, the main object is to produce a cloud of the highest possible

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initial concentration which will drift down wind and completely envelop the object attacked. Such a cloud should consist of a highly concentrated nucleus when liberated from the shell. This will drift down wind and expand by lateral rather than upward enlargement. The formation of such a cloud requires: First, complete vaporization at the moment of liberation; and second, a bursting charge which will completely shatter the shell, but which is not so strong as to give undue dissipation of the liquid contents, particularly in an upward direction. It is essential that the bursting charge should break the shell completely into small fragments. The more rapid and complete the break-up, the more concentrated is the cloud. Moreover, the loss of heat due to the sudden vaporization adds density to the cloud nucleus formed.

The *semi-persistent* gases boil between +20°C. and +200°C., i. e., above normal atmospheric temperature. With these gases to obtain a cloud nucleus of greatest possible concentration it is necessary to expel the liquid contents in a high state of atomization. This results in the most rapid vaporization with the least possible disturbance of the cloud. To secure this effect, the bursting charge should be of high power to insure maximum atomization, and yet not so high as to destroy the gas by dissociation. The object is to ensure that the liquid is converted into a cloud with least possible disturbance. This requires a more powerful bursting charge than the non-persistent gases and a shell of greater resistance,

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so that the liquid may be released under maximum pressure.

In the case of the *persistent* gases, boiling above +200°C. the object sought is quite different. Here, the cloud should be reduced to the minimum, and the area sprayed by the liquid contents of the shell increased to a maximum. This requires a large bursting charge of relatively high capacity but of slower action than the charge for the semi-persistent gases, and at the same time, a shell of relatively less strength than that required for complete atomization, but of sufficient resistance to give the maximum amount of coarse spray that will reach the ground as such. The charge which sprays the greatest area of ground and gives the minimum cloud is the one of maximum effectiveness. Due to their high boiling points, the persistent gases are relatively slow in their action, and hence prompt effects cannot be obtained unless the vaporization of the gas is secured by some artificial means. Such a means is a bursting charge developing high temperature and pressure, both of these conditions accelerating vaporization, the temperature acting directly and the pressure through increased pulverization. Consequently, if it is desired to obtain quick effect from persistent gases such as mustard gas, the shell should be loaded with a super-charge of high explosive, but it must be remembered that by so doing the gain in activity of the gas is obtained at the expense of greatly reducing its persistency. Another advantage

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in providing mustard gas shell with a super-charge of high explosive is that they detonate with the noise and the shock of a true high explosive shell and thus disguise the fact that they are gas shell. Recent developments in the use of mustard gas have indicated that a portion, at least, of these shell should be provided with a super-charge of high explosive to accelerate their action. If mustard gas shell having a super-charge of high explosive are used they will be stenciled with some distinguishing mark to indicate the fact that the bursting charge is above normal.

In general gas shell are similar to high explosive shell. In fact, the majority of gas shell in use at the present time are converted high explosive shell. While the principles involved in the design of gas shell are radically different from those affecting high explosive shell, it has been considered desirable to simplify the manufacturing program by converting high explosive shell into gas shell. As the proportion of gas shell to high explosive shell increases, it becomes more and more important for gas shell to be specially designed.

Gas shell consist of the shell body, which contains the gas; the gaine tube (adapter and booster casing), which screws into the nose of the shell and contains the bursting charge; and the bursting charge which consists of a small quantity of high explosive sufficient to open the shell, and in some cases, to atomize the liquid contents. Since most of the gases used

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enter the shell, as liquids, they expand as liquids when heated, and it is, therefore, necessary to leave a space for this expansion and only partially fill the shell. The void amounts to from 6% to 11% of the total capacity of the shell; depending upon the coefficient of expansion and the vapor pressure of the gas and the pressure which the joint between the shell and gaine tube will withstand.

There are various methods of making these joints gas tight:

(a) The general method employed by the British to prevent leakage of gas into the gaine tube, is to make the adapter and gaine tube of one piece, so that there is no joint through which gas may leak into the gaine tube. To prevent the gas from leaking through the joint between the adapter and the shell body, the British paint the threads with cement, screw the adapter in, and then "spin" over the exterior of the joint between the adapter and shell. This joint is made before the shell is filled and a test pressure of 100 lbs. per square inch is applied to the shell, through the filling hole in the side of the shell, to test the integrity of the joint. The shell is then filled and the filling hole plugged up with a small tapered iron plug.

(b) The French use, in some cases, a one-piece adapter and gaine tube. In other cases, however, the gaine tube is threaded into the adapter. The following is quoted from a French document and shows the method of closing the joint between the adapter and shell body:

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"To close this, we put in the first place between the bottom part of the head of the gaine and the machined shell, around the eye of the projectile, a pliable ring of lead tubing with a core of asbestos; in seating the gaine into the eye of the projectile, this ring is compressed and forms a dam between the head of the gaine and the throat of the eye of the shell. Furthermore, the threads are painted with a cement which is not attacked by the charging liquid and which in addition to stopping leakage adds very materially to the solidity of the union of the two parts."

(c) In the present American models of gas shell the gaine tube is welded to the adapter, though it is probable that, for certain gases at least, this method will be abandoned for a one-piece adapter and gaine tube. The joint between the adapter and the shell body is made gas tight by means of a tapered or pipe thread. The adapter and gaine tube are screwed into the shell until the tapered threads bind tightly and produce a gas tight joint. To facilitate assembling, the threads on the adapter are lubricated with oil, but no cement is used; dependence for gas tightness is placed entirely upon the metal to metal contact between the threads.

For certain gases, notably those containing bromine compounds, which have a corrosive action upon steel, it is necessary that the shell have a lining of glass or lead, and the gaine tube a coating of enamel, in order to protect the metal from the action of the gas.

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American chemical artillery shells are provided in the following calibers:

75 mm. Gun,
4.7" Gun,
155 mm. Gun,
155 mm. Howitzer,
5" S. C. Gun,
6" S. C. Gun,
8" S. C. Gun,
8" Howitzer,
9.2" Howitzer,
240 mm. Howitzer.

These shell are with colored bands to denote the different types of gases, as follows:

U. S. Symbol	U. S. Markings ½" Bands around Shell as Follows	U. S. Symbol	U. S. Markings ½" Bands around Shell as Follows
D.A.	1 White	B.A.	1 Red
C.G.	2 White	C.A.	2 Red
P.G.	1 White, 1 Red, 1 White	H.S.	3 Red
P.S.	1 White, 1 Red	W.P.	1 Yellow
N.C.	1 White, 1 Red, 1 Yellow	F.M.	2 Yellow

Red Bands denote persistency. *White Bands* denote non-persistency and lethal action. *Yellow Bands* denote smoke. *Purple Bands* denote incendiary. The number of bands indicates the relative strength of the property indicated. Thus, three red bands denote a gas more persistent than one red band, and three white bands indicate a gas where lethal action is greater than one marked with only one white band. The body of the shell is painted

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gray. The words "Special Gas" or "Special Smoke," as the case may be, are stenciled lengthwise of the shell in black block letters 5/8″ high. Incendiary shell are painted gray, with the word "Special Incendiary" stenciled lengthwise in black block letters 5/8″ high, but with no distinguishing bands.

The table on the following page shows the amounts of each kind of chemical filling contained in the different calibers.

With fixed ammunition (75 mm. and 4.7″), chemical shell are also marked on the base of the cartridge case by a black band 3/8″ wide and the words "Special Gas," "Special Smoke," or "Incendiary," in 1/4″ letters. The boxes in which chemical shell are packed are marked on each end with distinguishing bands and words used on the shell in addition to markings common to all artillery shell.

The system of weighing and marking of chemical shell follow the general scheme employed with high explosive shell, i.e., each caliber of shell is divided into a number of different weight lots and marked on the 75 mm. by crosses just above the rotating band, on the 4.7″ by squares just below the bourelet, and for calibers larger than 4.7″, by squares on the ogive. In addition, for calibers greater than 4.7″ the mean weight of the lot is stenciled on the shell, on 6″ shell just above the driving band and on other calibers on the ogive.

In addition to the use of smoke shell for smoke barrages, these are used for ranging gas shell. Gas shell of the French, British, and Germans all have

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Time	Calibers	Mark	Approximate weight of projectile less fuse and the filling in pounds	The Approximate Weight of Shell Filling							
				Gas						Smoke	
				H.S.	C.G.	N.C.	P.S.	C.A.	B.A.	F.M.	W.P.
				Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Field Gun....	75 mm.	II	10.27	1.35	1.32	1.74	.....	1.45	1.97	1.71	1.90
Gun....	4.7″	II	37.40	4.38	4.27	5.62	5.30	4.44	6.36	5.53	6.14
How....	155 mm.	II	80.80	11.30	11.00	14.50	13.66	12.18	16.41	14.30	15.85
Gun....	155 mm.	VII	79.45	11.30	11.00	14.50	13.66	12.18	16.41	14.30	15.85
Gun....	5″	VI	42.84	5.38	.....	.....	.....	.....	.....	6.70	.....
Gun....	6″	III	74.98	10.50	.....	.....	.....	.....	.....	13.28	.....
How....	8″	III	169.75	22.45	22.01	28.90	27.20	24.20	32.67	28.40	31.50
Gun....	8″	III	169.75	22.45	.....	.....	.....	.....	.....	28.40	.....
How....	9.2	*	252.45	29.45	28.69	37.80	35.62	31.70	42.78	37.20	41.30
How....	240 mm.	*	303.50	37.50	36.54	48.20	45.37	40.40	54.48	47.40	52.6

Of the fillings given in the above table it should be noted: N.C. is the same as P.S. except that it contains a stabilizer. B.A. and C.A. shell are both lachrymatory and can be used interchangeably, except that C.A. is several times more effective than B.A.

F.M. and W.P. shell are both smoke shell. F.M. is a liquid, and F.M. shell are therefore primarily intended for ranging gas shell. W.P. is a solid and produces a dense and more persistent smoke than F.M., hence W.P. shell should be used primarily for smoke barrages and screens.

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visible bursts, due to the presence of a smoke producing mixture in the shell. The French mix a "fumigène," or smoke producing compound, with the chemical filling. The British incorporate the smoke producing material with the bursting charge. The Germans produce a visible burst by use of a very large bursting charge. All of these methods reduce the efficiency of the shell and also have the disadvantage of producing a visible gas cloud whose limits are readily discernible by the enemy. All smoke producing compounds are omitted from American gas shell and the bursts are therefore, practically invisible. For ranging, therefore, it is necessary to have smoke shell of the same weight and ballistic characteristics as the gas shell. Smoke shell are first fired until the correct range has been ascertained, and then the fire for effect is continued with gas shell having invisible bursts.

By far the best smoke producing material for smoke barrages and curtains is white phosphorus, and this is used in all smoke shell intended for barrage purposes. These shell are known as W. P. shell and are marked with one yellow band. However, since phosphorous is a solid material, the W. P. shell is not accurate for ranging purposes, since shell filled with liquids (as all American gas shells are) have different ballistic characteristics and therefore different ranges from solid filled shell. For this reason it is necessary that smoke shell for ranging purposes be liquid filled. The best liquid smoke producing material is F. M.

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No satisfactory American incendiary shell has been developed as yet. The French have three calibers of incendiary shell—75 mm., 120 mm., and 155 mm. These are made from common high explosive shell by replacing a part of the explosive charge by a number of special incendiary cylinders, known as Incendiary Cylinder Ml. 1878. The Incendiary Cylinder Ml. 1878 consists primarily of a bundle of slow action quick match, tied with nitrated string, and internally and externally primed with a small quantity of ordinary quick match. This bundle is enclosed in a rectangle of cretonne cloth coated with an incendiary composition, and securely fastened with a heat-treated brass wire. The weight of the cylinder proper is 30 gr. and reaches 45 gr. when enclosed in a tar paper covering. On explosion of the projectile, the cylinder is ignited at both ends and projects 10 to 15 cm. fire jets for a period of 10 to 20 seconds, at the expiration of which time it burns, torch-like, for 70 to 80 seconds. Total combustion of the cylinder is, therefore, completed in approximately one and a half minutes.

The action of all percussion fuses is started by the flash produced by the contact of a firing pin with a special detonator called a primer. This primer is filled with a very sensitive mixture of fulminate of mercury and other ingredients. The construction of all percussion fuses is such that the primer and the firing pin cannot come in contact until the shell is fired, and they are then kept a small distance apart until the shell or fuse touches the ground. Then

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the firing pin and the primer are brought in contact in one of the following ways:

(a) The firing pin may be attached to a movable plunger at the front end of the fuse and be forced back into the fuse the instant the plunger comes in contact with the ground. This will cause the firing pin to hit the primer attached to the fuse body.

(b) The primer may be carried in a movable part inside the fuse. When the shell is checked by striking the ground the inertia of this movable part carries it on causing the primer to hit the firing pin.

It is evident that the action described in (a) will bring the needle in contact with the primer as soon as the resistance of the ground is sufficient to overcome the inertia of the plunger and force it into the fuse. It is, therefore, a quicker action than described in (b) which will take place only when the inertia of the shell itself has been overcome by the resistance of the ground.

Fuses having the action described in (a) are called "super-quick." Only such fuses are suitable for chemical shell. It is essential that a chemical shell should burst above ground. A fuse whose action is not super-quick allows the shell either to bury itself, at least partially, or to ricochet before bursting. If the shell is even partially buried before bursting the effectiveness of a part of the contents of the shell is lost due to its soaking into the ground. If the shell ricochets before bursting, the gas may be carried beyond the target.

Even with super-quick fuses, a certain amount of

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the effectiveness of the chemical shell is lost owing to the fact that the shell bursts at the ogive which leaves the base and part of the body more or less unbroken, and acts as a carrier for a certain portion of the liquid gases. If the angle of fall is low, the unbroken portion of the shell may ricochet and carry a portion of the gas past the target. If the angle of fall is great the unbroken portion will penetrate into the ground, thereby sealing its open end and preventing the liquid therein from being liberated.

In order that a super-quick fuse may function, it must land on its point. If the angle of fall is small the ogive of the shell will hit the ground first, the shell may then ricochet before the point of the fuse can come in contact with the ground, and the fuse will not function. For this reason, and for the reasons given above, chemical shell should be fired with reduced charges whenever possible. This should not, however, be carried to the extreme of using vertical fire, as by so doing the dispersion is greatly increased and the unbroken base and body of the shell will bury part of the contents.

Owing to the failure of super-quick fuses to function at low angles, and the increase in dispersion and decrease in range (caused by the great length of such fuses) when used with small calibers of shell, the French use short fuses, which are not super-quick, in the 75 mm. It is a question whether the increase in dispersion is more desirable than the loss of effectiveness due to the comparatively slow action of the short fuses.

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For smoke shell, when used for smoke barrages, and for gases such as mustard gas, it is sometimes highly desirable to have time fuses, allowing air bursts. With smoke shell air bursts permit the adjustment of the dimensions of the smoke cloud and thus greatly facilitate the establishment and control of effective smoke curtains. With vesicant gases, air bursts allow a greater and more efficient dispersion of the liquid contents. A combination fuse, combining a time element and a super-quick percussion element is now being developed, so as to enable batteries to conduct gas or smoke shoots with both ground and air burst. An effective combination fuse will also greatly reduce the number of duds, since its double action will cause the shell to explode on contact if it fails on time and vice versa.

The following are types of fuses suitable to use with chemical shell. These fuses have advantages and disadvantages:

French I. A. Model 1915, I. A. L. Model 1916, and **U. S. Mark III.**—The general functioning and construction of these three fuses are similar, the I. A. L. and the Mark III being successive modifications of the I. A. All are super-quick fuses, functioning by means of a plunger in the front of the fuse being driven into contact with a fulminate of mercury primer.

Arming.—The firing plunger is prevented from coming in contact with the primer during transportation, and while the shell is in the bore of the gun, by means of two steel half collars which engage with

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a shoulder on the firing plunger and prevent its movement to the rear. Two half collars are held in place by being wrapped with a brass ribbon on the end of which is a third half collar. The ribbon being wound in a direction opposite to the rotation of the gun, tends to tighten as long as there is rotational acceleration. When rotational acceleration is over, centrifugal force throws the third half collar out, and unwinds the ribbon, releasing the inner half collars and freeing the firing plunger. The firing plunger is prevented from being forced to the rear during flight by a shear wire.

Firing.—On impact the end of the plunger hits first and is driven into the body, shearing the shear pin, and impinging on the primer before the shell itself has touched the ground.

French R. Y. Model 1917.—This is a super-quick fuse and the following advantages are claimed for it over the I. A. L.: (1) It is safe, and (2) its shape is such as to produce better ballistic effects, and, therefore, less dispersion.

Action.—The firing pin and primer cannot come in contact until both have moved. On "set back," the plunger moves to the rear until the head engages with the body of the fuse. It is then as far to the rear as possible, and it becomes necessary for the primer to move forward to come in contact with the firing pin. The primer cannot move forward because the sleeve around the firing pin, at the bottom of which the primer is fastened, is engaged with the prongs of the upper half of the safety piece, which,

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in turn, is prevented from moving forward by engaging with the body of the fuse. On "set back," the lower half of the safety piece moves to the rear, freeing the upper half and allowing the upper half to move to the rear, the prongs being forced out of the groove in the primer sleeve. The upper half of the safety piece continues to "set back" until the prongs catch in the lower groove. The upper half of the safety piece is thus farther down on the primer sleeve than it was before the gun was fired.

After "set back" is over, and the velocity of the projectile begins to diminish, the inertia of the parts free to move causes them to "creep" forward. The upper half of the safety piece returns to its original position, carrying the primer sleeve and primer with it. The primer has thus moved forward in the fuse. At the same time the firing plunger "creeps" forward to its original position. On impact, the firing plunger is driven back to the position it had during the "set back." The primer, however, has moved forward, so that the firing pin now comes in contact with it.

The cover over the head of the firing plunger is painted red, and should not be removed.

French I Model 1914.—This is a fuse used extensively by the French for 75 mm. gas shell. The head of this fuse is usually painted red, though on certain models it is painted yellow. It has not been generally adopted, as it is considered unsafe, unless used with extreme caution.

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French Schneider Model 1916.—This is a non-super-quick fuse used by the French for 75 mm. gas shell. It causes considerably less dispersion than the I. A. L., but it is not considered quick enough for gas shell. It should not be used with gas shell of caliber greater than 75 mm. and should not be used when any of the super-quick fuses are available. The head of this fuse is painted white to indicate non-delay action. For it to function it is necessary for the primer pellet to move forward so that the primer comes in contact with the firing pin.

Modified British No. 106.—This is a fuse of the super-quick type and has only recently been adopted by us. It is suitable for all calibers and ranks next to the Mark III and I. A. L. fuses for chemical skill.

American 75 MM. *Common Steel Shell Mark II.*—This shell is marked and painted as stated in the following table:

Gases Used	The Shell Is Painted Slate Gray with the Following ½" Bands Around the Body	The Following Words Lengthwise on the Body.	Approximate Weight of Cases Pounds
H.S.	3 Red	Special Gas	1.36
C.A.	2 Red	Special Gas	1.46
B.A.	1 Red	Special Gas	1.97
N.C.	1 White, 1 Red, 1 Yellow	Special Gas	1.74
C.G.	2 White	Special Gas	1.32
F.M.	2 Yellow	Special Smoke	1.71
W.P.	1 Yellow	Special Smoke	1.90

The bottom of the cartridge case is marked with a black band 3/8" wide and the words "Special Gas," or "Special Smoke."

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The weights of the shell are the same as for high explosive shell and are marked as follows:

FROM Lbs.	Oz.	TO Lbs.	Oz.	Weight Mark Just Above Driving Band.
10	11	11	0	L
11	0	11	5	+
11	5	11	11	++
11	11	12	0	+++
12	0	12	5	++++

Immediately above the weight marks, and on the side of the shell opposite the words "Special Gas" are the letters 75-G.

The following fuses are authorized for use with these shell: U. S. Mark III, French I. A. L., Model 1916, French I. A., Model 1915, Modified British No. 106 (when issued), French R. Y., and French Schneider, Model 1916.

French 75 MM, Steel Shell Model 1915.—The filling, marking, etc., of these chemical shell in common use are enumerated in the following table:

No.	Filling	U. S. Symbol	Marking The shell is painted green with the following distinguishing marks	Weight of Gas in Pounds Approximate
2	Incendiary	Incendiary	Red Ogive, No. 2 on Ogive	....
3	Smoke	W.P.	Red Ogive, No. 3 on Ogive	1.06
5	Collongite	C.G.	1 White band around body, No. 5 on Ogive	1.55
7	Aquinite	N.C.	1 Orange Yellow band around body, No. 7 on Ogive	1.76
9	Martonite	B.A.	1 Orange Yellow band around body, No. 9 on Ogive	1.34
20	Yperite	H.S.	2 Orange Yellow bands, No. 20 on Ogive	1.31
21	Camite	C.A.	1 Orange Yellow band No. 21 on Ogive	1.52

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On the ogive, immediately below the number of the mixture, are letters indicating its nature. With No. 20, "Yt" indicates Yperite dissolved in carbon-tetrachloride, and "Yc" indicates Yperite dissolved in monochlorbenzene. Immediately below these letters, the date and place of fillings are placed. "Aub" for Aubervilliers, "Vis" for Vincennes, "P.Cx" for Pont-de-Claix. With the exception of No. 20 and No. 21, the above mixtures contain a percentage of opacite (stannic chloride) added to produce smoke. The numbers of the mixtures are also placed on the base of the cartridge case. The weight classification and weight marking of this shell are the same as the U. S. 75 mm. The same fuses are to be used with this shell as with the U. S. 75 mm.

American 4.7" Common Steel Shell Mark II. —The painting and marking of these shell are as stated in the following table:

Gases Used	Shell Is Painted Slate Gray		Approximate Weight of Gases, Lbs.
	With the Following ½" Bands Around the Body	And following Words Lengthwise on the Body	
H.S.	3 Red	Special Gas	4.38
C.A.	2 Red	Special Gas	4.44
B.A.	1 Red	Special Gas	6.36
P.S.	1 Red, 1 White	Special Gas	5.3
N.C.	1 Red, 1 White, 1 Yellow	Special Gas	5.62
C.G.	2 White	Special Gas	4.27
F.M.	2 Yellow	Special Smoke	5.53
W.P.	1 Yellow	Special Smoke	6.14

The bottom of the cartridge case is marked with a black band 3/8" wide and the words "Special

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Gas," "Special Smoke" or "Incendiary." The weights of the shell are the same as for high explosive shell.

The following fuses are authorized for use with this shell: U. S. Mark III, French I. A. L. Model 1916, French I. A. Model 1915, Modified British No. 106 (when issued), and French R. Y.

A 4.7" semi-steel shell Mark V has also been developed which differs from the steel shell only in that the net capacity is reduced from 92.4 cu. in. to 90.9 cu. in.

American 5-inch Common Steel Shell Mark VI.—The painting and marking of these shell are as stated in the following table:

Gases Used	Shell Is Painted Slate Gray		Approximate Weight of Gases
	With the Following ½" Bands Around Body	And Following Words Longitudinal on shell	
H.S. F.M.	3 Red 2 Yellow	Special Gas Special Smoke	5.38 6.79

The following fuses are authorized for use with these shell: U. S. Mark III, French I. A. L. Model 1916, French I. A. Model 1915, Modified British No. 106 (when issued), and French R. Y.

A 5-inch semi-steel shell has also been developed which differs from the steel shell only in reduced capacity.

American 6-inch Common Steel Shell, Mark

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III, for Gun.—The painting and marking of these shell are as stated in the following table:

Gases Used	Shell Is Painted Slate Gray		Approximate Weight of Gases, Lbs.
	With the Following ½" Bands Around Body	And Following Words Lengthwise on Body	
H.S. F.M.	3 Red 2 Yellow	Special Gases Special Smoke	10.50 13.28

The following fuses are authorized for use with these shell: U. S. Mark III, French I. A. L. Model 1916, French I. A. Model 1915, Modified British No. 106 (when issued), and French R. Y.

A 6-inch semi-steel shell has also been developed which differs from the steel shell only in reduced capacity.

American 155 MM. Common Steel Shell, Mark II, for Howitzer.—The painting and marking of these shell are as stated in the following table:

Gases	Shell Is Painted Slate Gray		Approximate Weight of Gases, Lbs.
	With the Following ½" Bands Around Body	And Following Words Lengthwise on Body	
H.S.	3 Red	Special Gas	11.3
C.A.	2 Red	Special Gas	12.18
B.A.	1 Red	Special Gas	16.41
P.S.	1 Red, 1 White	Special Gas	13.66
N.C.	1 Red, 1 White, 1 Yellow	Special Gas	14.5
C.G.	2 White	Special Gas	11.0
F.M.	2 Yellow	Special Smoke	14.30
W.P.	1 Yellow	Special Smoke	15.85

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The following fuses are authorized for use with these shell: U. S. Mark III, French I. A. L. Model 1916, French I. A. Model 1915, Modified British No. 106 (when issued), and French R. Y.

A 155 mm. semi-steel shell has also been developed which differs from the steel shell only in reduced capacity.

French 155 MM. Semi-Steel Shell, Model 1915, for Howitzer.—The following are the 155 mm. howitzer French chemical shell in common use:

Filling		U. S. Symbol	Marking The Shell Is Painted Green with the Following Distinguishing Marks	Approximate Weight of Gas, Lbs.
No.	Name			
Type Naud	Incendiary	Incendiary	Red Ogive—1 black ring....	...
5	Collongite	C.G.	1 White band around body—No. 5 on Ogive.....	9.0
7	Aquinite	N.C.	1 Orange Yellow band around body—No. 7 on Ogive....	10.7
9	Martonite	B.A.	1 Orange Yellow band around body—No. 9 on Ogive....	7.46
20	Yperite	H.S.	2 Orange Yellow bands—No. 20 on Ogive.....	7.6
21	Camite	C.A.	1 Orange Yellow band—No. 21 on Ogive.....	8.83

On the ogive, immediately below the number of the mixture, are letters indicating the nature of the mixture. With No. 20, "Yt" indicates Yperite dissolved in carbontetrachloride, and "Yc" indicates Yperite dissolved in monochlorbenzene.

Immediately below these letters are indicated the date and place of filling: "Aub" for Aubervilliers, "Vis" for Vincennes, and "P.Cx" for Pont-de-Claix.

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With the exception of No. 20 and No. 21, the above mixtures contain a percentage of Opacite (stannic chloride) added to produce smoke.

American 155 MM. Common Steel Shell, Mark VII, for Gun.—These shell are the Mark II howitzer shell, modified for use in the 155 mm. gun. They have two driving bands.

Gases Used	Shell Is Painted Slate Gray		Approximate Weight of Gases, Lbs.
	With the Following ½" Bands Around Body	And Following Words Lengthwise on Body	
H.S.	3 Red	Special Gas	11.30
C.A.	2 Red	Special Gas	12.18
B.A.	1 Red	Special Gas	16.41
P.S.	1 Red, 1 White	Special Gas	13.66
N.C.	1 Red, 1 White, 1 Yellow	Special Gas	14.50
C.G.	2 White	Special Gas	11.00
F.M.	2 Yellow	Special Smoke	14.30
W.P.	1 Yellow	Special Smoke	15.85

The following fuses are authorized for use with these shell: U. S. Mark III, French I. A. L. Model 1916, French I. A. Model 1915, Modified British No. 106 (when issued), and French R. Y.

A 155 mm. semi-steel shell has also been developed which differs from the steel shell only in reduced capacity.

French 155 MM. Semi-Steel Shell, Model 1917, for Gun.—These shell are the model 1915 howitzer shell modified for use in the 155 mm. gun. They have two driving bands.

The following are the 155 mm. howitzer French chemical shell in common use:

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Filling		U. S. Symbol	Marking The Shell Is Painted Green with the Following Distinguishing Marks	Approximate Weight of Gas, Lbs.
No.	Name			
5	Collongite	C.G.	1 White band around body—No. 5 on Ogive.....	9.0
7	Aquinite	N.C.	1 Orange yellow band around body—No. 7 on Ogive....	10.7

On the ogive, immediately below the number of the mixture are letters indicating the nature of the mixture. Immediately below these letters are indicated the date and place of filling "Aub" for Aubervilliers, "Vis" for Vincennes, and "P.Cx" for Pont-de-Claix. On the body are the letters G.P. in white, indicating that it is a gun shell.

The above mixtures contain a percentage of Opacite (stannic chloride) added to produce smoke.

The weight classifications and weight markings of this shell are the same as for the U. S. 155 mm. gun shell.

The same fuses are to be used with this shell as with the U. S. 155 mm. gun shell.

American 8-inch Common Steel Shell Mark III.—The same shell is used for both howitzer and gun, but only the H. S. and F. M. fillings are used in the gun. The painting and marking of these shell are as stated in the table on page 92.

Immediately above the driving band are the letters "8-GH" indicating that the shell may be used in either the 8″ gun or the 8″ howitzer.

The following fuses are authorized for use with

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these shell. U. S. Mark III, French I. A. L. Model 1916, French I. A. Model 1915, Modified British No. 106 (when issued), and French R. Y.

Fillings for Howitzer Shell

Gases Used	Shell Is Painted Slate Gray		Approximate Weight of Gases, Lbs.
	With the Following ½" Bands Around Body	And Following Words Lengthwise on Body	
H.S.	3 Red	Special Gas	22.45
C.A.	2 Red	Special Gas	24.20
B.A.	1 Red	Special Gas	32.67
P.S.	1 Red, 1 White	Special Gas	27.20
N.C.	1 Red, 1 White, 1 Yellow	Special Gas	28.90
C.G.	2 White	Special Gas	22.05
F.M.	2 Yellow	Special Smoke	28.4
W.P.	1 Yellow	Special Smoke	31.5

An 8" semi-steel shell has also been developed which differs from the steel shell in reduced capacity only.

9.2-inch and 240 MM. Chemical Shell.—These shell are both steel and semi-steel, and use the following fillings:

Gases Used	The Shell Is Painted Slate Gray	
	With the Following ½" Bands Around the Body	And the Following Words Lengthwise on the Body
H.S.	3 Red	Special Gas
C.A.	2 Red	Special Gas
B.A.	1 Red	Special Gas
P.S.	1 Red, 1 White	Special Gas
N.C.	1 Red, 1 White, 1 Yellow	Special Gas
C.G.	2 White	Special Gas
F.M.	2 Yellow	Special Smoke
W.P.	1 Yellow	Special Smoke

These shell take the same fuses as are used with other calibers.

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CHAPTER VII

Smoke for Military Purposes, Phosphorus and Tetrachlorides, British "S" and B. M. Mixtures, Smoke Screens, Smoke Shell, Protection of Tanks.

Phosphorus, tin, titanium, silicon and special smoke mixtures are commonly employed for producing smoke for military purposes. Phosphorus, when exposed to air, quickly produces great volumes of dense white smoke, the particles burning on the ground persisting for several minutes. Phosphorus gives smoke of the highest obscuring power and greatest persistency of any of the smoke producing substances. The burning particles of phosphorus make deep and serious burns in flesh and hence it has a decided value against troops exposed to it. Phosphorus is therefore used for smoke barrages and screens, in artillery shell, trench mortar bombs, and hand and rifle grenades. Tin, silicon, and titanium (tetrachlorides) are liquids which give smoke when liberated in the air. They are not as effective as phosphorus for smoke barrages and screens because their smokes have a smaller obscuring power and less persistency. They are, however, more abundant than phosphorus and are in the nature of substitutes where phosphorus cannot be obtained. These materials are, therefore, loaded as phosphorus substitutes into artillery shell, trench mortar bombs, and hand gre-

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nades. Due to the fact that these substances are liquids, they are peculiarly suited for smoke ranging shell, as they exhibit the same ballistic characteristics as liquid gases. The relative merits of these three substances are as in the order named, and, as compared with white phosphorus, may be taken in the proportion of 2 to 5.

Other smoke mixtures include the British "S" mixture, consisting essentially of saltpetre, sulphur, pitch, borax and glue, and the "B. M." mixture, consisting essentially of powdered zinc, carbon tetrachloride, sodium chlorate and magnesium carbonate. The British "S" mixture has been used in smoke candles effectively and as compared with phosphorus has a screening value in the proportion of 1 to 5. The "B. M." mixture is often used as a substitute for phosphorus in hand grenades and smoke candles, and has an obscuring value equal to phosphorus and a relative persistency of about one-half that of phosphorus.

Smoke is most commonly used by (1) Artillery, with smoke shell for distant smoke barrages and for ranging gas shell. (2) Infantry, with Stokes 3-inch smoke bombs for smoke screens up to a range of 1,800 yards; with hand and rifle smoke grenades to protect advancing troops against machine gun nests, etc.; with smoke candles to conceal troop movements, etc. (3) Gas troops, with Stokes 4-inch smoke bombs for conducting special tactical operations, often combining with use of gas; for establishing smoke screens of large dimensions up to a range of 1,000 yards. (4) Air service, with small smoke drop bombs used for training observers in bomb dropping, etc.

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Smoke, when its use is carefully studied and understood, will be found of great value in modern infantry tactics, as it confers many of the advantages which are to be gained by conducting operations at night, while few of the disadvantages are present. Use of smoke must be very carefully planned in order to avoid certain serious disadvantages likely to accrue under conditions unfavorable to its use or if smoke be improperly employed.

Smoke screens may be employed with one or more of the following objects in view:

(a) To mask known enemy observation posts: to conceal and protect the front and flanks of attacking troops from enemy observation; and to blind hostile machine guns.

(b) As a feint to draw the enemy's attention to a front on which no attack is being made, so as to hold his troops to their positions and prevent them from rendering assistance to the sector attacked; in inducing him to expend ammunition needlessly and to put down a barrage in the wrong place.

(c) In the case of a smoke cloud used offensively to simulate gas, with a view to lowering the enemy's morale and forcing him to use his gas masks. It may also be used to extend the front of a gas attack. To make this effective, gas should occasionally be mixed with smoke in order to impress upon the enemy the belief that it is never safe to remain in a smoke cloud without wearing his mask.

(d) In flat or open country to conceal concentrations of guns and troops, and to screen roads, forming-up places and lines of advance; also to blind the flashes of a battery in action in view of the en-

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emy's observation posts and to hamper observation from the air.

(e) To cover or hide the construction of bridges, trenches, etc., in the face of the enemy.

Ground and troops behind smoke screens can seldom be concealed from hostile airplanes or kite balloon observation.

If troops are hidden in smoke clouds such clouds attract the enemy's fire and are therefore dangerous; for this reason, smoke screens intended to conceal concentrations should normally be formed at some distance—about 400 yards—from the object to be concealed.

In frontal screens, care must be exercised to place the screen so that an enemy barrage laid on it will not catch advancing troops. Such a screen should preferably be placed on the enemy trench system.

The necessity for anticipating the effect which a smoke cloud will have in impeding our own observation and artillery fire should be considered, as well as the possibility of troops being hidden from our contact patrol airplanes.

When smoke is liberated on the flank of an assault, care should be taken, by defining permissible wind limits beforehand, that the cloud does not pass across the front of the assaulting troops, as the latter attacking through smoke are very liable to lose direction.

When the use of a smoke screen in operation is contemplated, the enemy should be educated to associate such a screen with some object other than the real one, e. g., he may, by means of a practice smoke screen, followed by no action, be led to sup-

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pose that the object of the demonstration is to compel him to expend ammunition uselessly.

It is obvious from the foregoing that it is of the utmost importance that the use of smoke should be systematic but varied instead of casual and haphazard. Initiative at the critical moment means the saving of valuable lives and the avoidance of delay in the progress of the attack. If this is to be cultivated, and if misuse and waste are to be prevented, the most careful training is required, not only of the individual, but also of companies, battalions, and even brigades.

The amount of smoke-producing material required to form a screen depends on a number of considerations, the most important of which are as follows: (a) The extent of the screen. As a rough guide it may be assumed that the width of the screen should be from two to three times the width of the object to be concealed (as seen by observers from the points from which it is intended to prevent observation). (b) Duration of the screen. (c) The direction of the wind. A cross wind requires, as a rule, less expenditure of smoke than one at right angles to the front; and the difficulty of concealment increases if the direction of the wind is variable. (d) The velocity of the wind. The density of the smoke cloud diminishes considerably in proportion as the velocity of the wind increases. In a wind of over 20 miles per hour it is very difficult to form an opaque screen without excessive expenditure of material. (e) The number of directions from which the enemy can observe the object or area to be concealed. The greater the num-

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ber of points from which an object can be observed by the enemy, the greater will be the extent of the screen required and therefore of the amount of smoke producing substances necessary to form it. (f) The distance of the object from the enemy's observation posts. The greater this distance the more effective the smoke cloud will be.

In forming a screen with any form of smoke producer, it is necessary for the formation of the smoke screen to be very carefully organized, so that the best results may be obtained with the greatest economy of material. All personnel required for providing smoke screens should be trained beforehand in the use of the actual material which is to be employed and a simple rehearsal is most valuable. The program which is to be followed should state in detail the rate of expenditure of the smoke producing substances and should be given in writing to the personnel at each smoke source.

Since the enemy artillery is the most dangerous adversary of the tanks, one of the vital conditions for the successful operations of tanks is blinding the ground observation posts which look out on the field of attack by means of a very dense well regulated smoke screen. In front of the artillery in position, a natural or artificial fog is a necessity to the tanks. Batteries assigned to support infantry, especially when latter is supported by tanks, and artillery assigned to direct support of tanks should have on hand at all times a sufficient supply of smoke shells to take prompt advantage of opportunities for its use. The efficacy of smoke screen properly placed in assisting tanks to accomplish their mission has been amply demonstrated in action.

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Smoke shells should not be employed in the rolling barrage alone. In different sections, notably that just cited, the method of forming a "smoke cage," or box barrage, gave excellent results. This method consists in establishing a smoke barrage on all points from which the objective to be taken could be seen at a distance of 500 to 600 meters. An enclosed area is thus formed in which the infantry and tanks may operate, screened from the view of the enemy observers, without themselves being bothered by lack of visibility within combat distance.

Gas and smoke, during a withdrawal or on stabilized fronts, should be used according to the directions given. On a retirement maximum amounts of mustard gas should be used from close up to the retiring troops to as far back as the longest range guns will reach.

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CHAPTER VIII

Chemical Weapons for Use by Infantry, Incendiary Grenades, Thermit Hand Grenades, Tactical Use of Gas Grenades, Tactical Use of Smoke Grenades, Smoke Candles, Stokes Mortar Smoke Bombs.

The following types of chemical weapons have been approved for use by infantry: Incendiary grenades, gas grenades, smoke grenades, smoke candles and 3-inch Stokes mortar smoke bombs. The *incendiary grenades* include the French "grenade-incendiaire à Main" and "U. S. Thermit hand grenade, Mark I." The *gas grenades* include the "French Suffocante et Lachrymogène" hand grenade, British "No. 28, Chemical Hand Grenade, Mark II," and U. S. "Gas Hand Grenade, Mark II." The *smoke grenades* include the French "Incendiaire et Fumigène" Hand Grenade, the British "No. 27 Hand or Rifle Grenade, Mark I," and U. S. "Phosphorus Hand Grenade, Mark II." The *smoke candles* include the British "Smoke Candle, Mark I (L) Type S," the British "Smoke Candle, Mark II (L) Type S-1," and the U. S. "Smoke Torch, Mark I." The *3-inch Stokes mortar smoke bombs* are manufactured in the United States and contain approximately three pounds of white phosphorus or its equivalent.

French "Grenade-Incendiaire à Main."—This grenade consists of a cylindrical shell of tin plate to

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which the top and bottom are attached by crimping and soldering. In the cover is a hole into which is soldered a metallic ring, tapped to receive the firing mechanism. It has a percussion cap provided with a Bickford fuse, and carries a charge of thermit with a mixture of special ignition material. The grenade body is approximately 5 7/8" long and 2 1/2" in diameter. The total weight of the charged grenade is about 750 grammes or 1.65 pounds.

Method of Use.—Hold the grenade in the hand, grasping the body firmly, and with the other hand remove the cover cap. Force the striker in sharply by striking it a keen blow against a hard body such as the heel, a rock, the butt of the gun, etc. The grenade takes fire in five seconds after the percussion and burns without exploding.

Action.—The percussion of the primer ignites the Bickford fuse. Its combustion requires five seconds, after which the quickmatch is lighted. This, in turn, ignites the special igniting mixture. By reason of the delay and absence of explosion the grenade can be placed by hand, or thrown to a distance.

U. S. Thermit Hand Grenade Mark I is an exact duplicate of the French "Grenade Incendiaire à Main." This grenade is effective because of the intense heat of the molten material. It should be placed above the object to be burned and not underneath it. It is placed by hand and used principally for the destruction of non-combustible material. It contains a thermit mixture which produces an exceedingly high temperature, the contents becoming a mass of white-hot molten metal. It is used by raiding parties, where a permanent advance is not con-

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templated, for the purpose of destroying enemy trench mortars, machine guns, etc., which cannot be brought back to our own lines. The incendiary grenade is ignited and dropped down the muzzle of a mortar or placed in contact with some vital part with the result that the gun is ruined. A few men in each raiding party should be taught how to use these grenades.

In destroying tanks of gas or oil, it is necessary to increase the time of burning of the fuse. In such cases, to give the operators time to reach a place of safety, it is necessary to replace the cap by a piece of Bickford fuse of the desired length which can be fired with a match. For this substitution make a tube out of paper through the center of which the fuse is passed. Bind it with a thread to the collar of the grenade and then to the cord. Avoid getting the material wet during the operation.

Grenades which have not taken fire can be picked up without danger and used again after having changed the fuse.

French "Suffocante et Lachrymogène" Hand Grenade.—This grenade consists of the following parts: The body of the grenade, the collar, the gaine, and the automatic firing mechanism. The grenade is filled with "Papite" (acrolein), a liquid gas that is both lethal and lachrymatory. The body of the grenade is the same as the French "Grenade-Incendiaire et Fumigène, Mle. 1916 Automatique" with the exception that there is an orifice in but one end. This orifice is for the reception of a brass collar which is inserted therein and soldered to the body of the grenade. The collar is threaded internally for the reception of a hollow brass plug which

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is screwed into it and thus secured in the grenade. The gaine, made of tin, is soldered to the lower part of the hollow brass plug and carries the detonator, which is the bursting charge of the grenade. A rubber washer placed between the top of the collar and the shoulder of the plug forms a liquid tight joint. The hollow brass plug is threaded internally to receive the automatic firing mechanism. A leather washer is inserted between the top of the hollow brass plug and the shoulder of the automatic firing mechanism to form a tight joint. The total weight of the charged grenade is 400 grammes or 0.9 pounds.

Method of Use.—Hold the grenade in the throwing hand, the firing mechanism up, in such a manner as to secure the lever. Pass the index finger of the free hand through the ring and withdraw the safety pin. The grenade is now armed and the bomber must take every precaution not to release the grip on the lever until the grenade is thrown. The grenade bursts five seconds after the action of the automatic firing mechanism, and produces a cloud of fine particles, intensely irritating to the respiratory passages. This causes violent coughing, and does not kill or seriously injure, but has considerable moral effect.

Action.—After being thrown, the lever, which is no longer held by the safety pin, is projected from the grenade by the bolt. The removal of the lever permits the functioning of the automatic firing mechanism which sets off the primer. The primer ignites the slow fuse, which, after five seconds fires the denotator, exploding the grenade.

British No. 28, Chemical Hand Grenade, Mark

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II.—This grenade consists of the following parts: The body, the gaine, and the firing mechanism. It is filled with K. J. (stannic chloride). The body is made of cast iron, spherical in form and 3 3/8" in outside diameter. A boss is cast on the body through which is tapped a hole for the reception of the gaine. The gaine or denotator sleeve is also made of cast iron, on the open end of which is provided an externally threaded boss for the assembly of the firing mechanism, which is similar in construction to that used on the British "Grenade, Hand or Rifle, No. 27, Phosphorus, Mark I."

Method of Use.—When used as a hand grenade its manipulation is the same as the British No. 27. The effect of the grenade is essentially the same as the French "Grenade-Suffocante et Lachrymogène, Mle. 1916, Automatique."

U. S.—"Gas Hand Grenade, Mark II." This grenade is the same as the French "Suffocante et Lachrymogène" hand grenade.

Method of Use.—The method of using the U. S. "Gas Grenade Mark II," is entirely similar to the French "Grenade-Suffocante et Lachrymogène, Mle. 1916, Automatique."

Action.—The grenade and lever are firmly grasped in the throwing hand in such a manner as to secure the lever. The safety split pin is removed with the free hand and the grenade is ready to throw. The thrower must take every precaution not to release the grip on the lever until he throws the grenade. Upon release of the lever, the striker impelled by its stiff spring rotates around the hinge pin, forcing up the lever, and strikes the primer, first perforating the tinfoil disc which is sealed over the top

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of the cap to waterproof the primer. The end of the fuse is tipped with a priming powder composition, which ignited by the primer in turn ignites the fuse. In five seconds the flame from the fuse spits into the fulminate composition of the detonator causing it to explode. The explosion of the detonator is sufficient to burst the body of the grenade and scatter the contents in all directions.

Gas grenades are intended for the use of "mopping up" parties in driving the enemy out of dugouts. This is generally more effective than blowing in the dugout with a charge of high explosive. A cloud is formed which violently attacks the eyes, nose and throat and penetrates to a large extent the enemy respirator. While not fatal, the fumes are unbearable in a close space, and the enemy is forced to come out choking and blinded. Four or five grenades should be carried by two men in each squad of a "mopping up" party. Upon coming to an enemy dugout, which is suspected of being inhabited, three or four grenades are tossed inside the entrance without exposing the grenadiers to fire from below. Occasionally they may be found of value in driving the enemy from a machine gun nest or strong point, when such a position is located downward.

French "Incendiaire et Fumigène" Hand Grenade.—This grenade consists of the following parts The body, the gaine, and the automatic firing mechanism. The body, ovoid in form, is nine centimeters long, and six centimeters in diameter, at the center. It is made of two ovigal caps of tin, set, clasped and soldered to each other around the edges of their large bases. After filling, the hole

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is hermetically sealed by a disc of tin soldered to the body of the grenade. The gaine, made of special metal, holds the charge of explosive powder. It is threaded on the interior to receive the fuse plug which forms the body of the firing mechanism, which is automatic but is without a detonator. The fuse requires five seconds for combustion. A rubber washer placed between the upper flange of the gaine and the shoulder of the fuse plug, forms a tight joint for the grenade. The total weight of the charged grenade is 560 grammes or 1.23 lbs., and the charge is 300 grammes of white phosphorus.

Method of Use.—Hold the grenade in the throwing hand, the firing mechanism up, in such a manner as to secure the lever. Pass the index finger of the free hand through the ring and withdraw the safety pin. The grenade is now armed and the bomber must take every precaution not to release the grip on the lever until the grenade is thrown.

The grenade when thrown, bursts into flames five seconds after the lever is released, producing a cloud of dense white smoke and suffocating vapors. The range of the grenade is 25 to 30 meters. Its explosion does not produce any dangerous metallic pieces but throws in all directions within a radius of 15 to 20 meters pieces of burning material (W. P.) capable of causing serious burns and which also constitute a possible source of fires. The burning of this material is prolonged for several minutes after the explosion, forming an abundance of white smoke. With a favorable wind, 20 grenades are sufficient to create an extended smoke cloud.

Action.—Upon leaving the hand of the thrower,

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the lever, which is no longer held by the safety pin, is projected from the grenade by the bolt. The removal of the lever permits the functioning of the automatic firing mechanism which sets off the primer. The primer ignites the slow fuse which after five seconds ignites the black powder charge in the gaine. This explodes the grenade with sufficient force to scatter the burning contents over a radius of 15 to 20 meters and at the same time produces an intense and suffocating vapor within a radius of 5 to 6 meters.

British "No. 27, Hand or Rifle Grenade, Mark I."—This grenade consists chiefly of the following parts: the body, the gaine, and the firing mechanism. The body of the grenade, cylindrical in form, is about 3 3/4″ long and 2 1/4″ in diameter. It is made of tinned plate and is capped on either end with dished tinned plate stampings somewhat heavier than the metal forming the body. To the lower cap, forming the base, is soldered a steel plate approximately 1/4 inch thick. This steel plate is tapped to receive a rod fifteen inches long and of the proper diameter to fit the bore of the service rifle. The rod is used only when the grenade is projected with a rifle. The rods are issued detached from the grenades in the ratio of 60% of the grenades. To the upper cap, forming the cover of the body, is soldered a spigot, externally threaded to hold the firing mechanism. The gaine is inserted through the spigot and the cover, and is soldered to the spigot. The primer rests on top of the spigot and is held in place by the striker chamber. The primer is crimped to the fuse, on the other end of which is crimped the detonator, the fuse and deto-

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nator extending into the gaine. The striker is held by a shear wire. Over the entire firing mechanism is placed a metal cover, to prevent accidental discharge, the cover being held in place by means of a retaining pin and ring. A small hole is provided in the cover cap for filling. This is sealed with a disc of tin. The filling charge is about 400 grammes of white phosphorus.

Method of Use.—(a) As a Hand Grenade. The cap over the firing mechanism is removed after withdrawing the retaining pin. The striker is then struck against any solid object, as the heel of the boot, the butt of the gun, a rock, etc.. The shock shears the small restraining wire and the striker point fires the primer and starts the fuse burning. (b) As a Rifle Grenade. The stem is attached by screwing it into the base plate of the grenade as far as it will go. The protecting cap is then removed, exposing the striker. A blank cartridge furnished for this purpose is next loaded into the rifle, after which the grenade rod is inserted into the muzzle of the rifle and pushed down as far as it will go. The butt of the gun is set against some solid object, such as the bottom of the trench, a sandbag, etc., and the elevation adjusted according to the range desired. Upon the discharge of the rifle the setback shears the small restraining wire, permitting the striker point to impinge upon the primer, thus igniting the fuse which in five seconds fires the detonator. The maximum range is obtained with the rifle held at 45 degrees. Shorter ranges may be had by either raising or lowering this elevation. Under favorable conditions, ranges up to 230 yards are obtained. The effect of this grenade is similar to that

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of the French Grenade "Incendiare et Fumigène Mle. 1916, Automatique."

U. S. "Phosphorus Hand Grenade Mark II."—This grenade is essentially the same as the French "Incendiaire et Fumigène," hand grenade.

Smoke grenades have been primarily designed as infantry weapons for offensive operations both as incendiary and smoke producing articles. They are suitable for burning dugouts, blinding machine guns, or screening small local attacks. Due to their scarcity, their use in producing smoke screens is uneconomical. These grenades on exploding scatter burning phosphorus over a circle of 15-20 meters radius.

Used as Rifle Grenades.—The British Grenade the "No. 27, Hand and Rifle Mark I," is the only chemical grenade which has been designed for rifle projection. The other smoke grenades described are designed for hand projection only.

The rifle smoke grenade is most effective in brush or wooded country, particularly where the terrain is undulating, thus permitting a detachment of grenadiers to crawl within range of a machine gun without exposing themselves to severe fire. Unless there is natural cover at the firing point rifle pits should be scooped out so that the grenadiers will have protection from machine guns.

Two or three grenadiers should keep up a continuous fire upon the machine gun attacked. Others are designated to work their way into close striking distance from whence they can rush the gun from the flank, under cover of the smoke. The rifle grenade is most effective when burst ten or fifteen feet above the ground.

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The smoke generated by the burning phosphorus cuts off the machine gun from the possibility of direct fire. This effect may often be obtained, even though the strong point is out of range, if it is possible to work into a position to the windward so that the smoke will drift over the point to be screened.

If an attack is held up by hostile machine guns, their position might be indicated by firing single rifle grenades toward them, targets being thus provided on which fire from other weapons can be directed.

Two men in each squad may be trained to use these grenades and they should carry ten each in an advance.

Used as Hand Grenades.—All of the smoke grenades can be used as hand grenades. The principal use of the phosphorus hand grenade is as a follow-up of a rifle grenade, for the maintenance at short range of the smoke cloud when taking a strong point. The smoke given off by the rifle grenades permits the grenadiers to advance to a point where the hand grenades may be used. A minor use for the hand smoke grenade is in "mopping up" the enemy dugouts, although the gas grenade is more effective for this purpose.

British "Smoke Candle, Mark I. (L) Type S."—This smoke candle consists of the following parts: Case, lid, tin plate cover, striker, igniting device, charge, powder discs, cap and band. The case is made of tinned iron plate, having a welded side and bottom seam and four plugs to secure the lid. The lid is made of material of the same quality as the case. It is pressed to the required form and has a central hole and four slots around its edge. The

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cover is made of tin plate. The striker is made of strong durable tape. Secured to this tape, by means of glue and two wire stitches, is a cardboard disc coated with match box composition in the uncovered side. The case is charged with smoke composition.

Method of Operation.—Tear off the top by pulling the tape quickly upwards. Ignite the flare by rubbing the red disc sharply and firmly across the black blob on its center. This operation ignites the match material which in turn ignites the quick match, which sets fire to the fire composition for lighting the smoke mixture. This burns and gives off a smoke for three minutes.

British "Smoke Candle Mark II. (L) Type S-1."—This candle consists of the following parts: Case, lid, projector, friction thimble, striker, and igniting arrangement. The case is made of tinned iron plate of the form and of dimensions regularly adopted, and has a welded side and bottom seam. The lid is made of stamped tinned plate and fits tightly on the case. The protection and friction thimble is stamped from tinned plate, the projector being slotted to allow for the passage of the tape and striker arrangement. The striker is made of strong tape, to which is fastened by means of glue and two wire stitches, a cardboard disc, coated with match box composition. A piece of paper is secured to the tape on the same side as the disc in such a manner as to cover the striker. The case is filled with about 3 pounds of smoke composition in a plastic or semi-fluid condition.

Method of Operation.—To fire, tear off the tape to expose the firing composition. Rub the tablet of red composition, which is attached to the underside

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of the tape, smartly across the black blob of composition in the center of the top of the candle. This operation causes the match material to ignite the igniter which sets fire to the smoke composition. This burns and gives off smoke for five minutes.

U. S. "Smoke Torch, Mark I."—The general construction and method of operation of this candle is entirely similar to that of the British "Smoke Candle Mark I (L) Type S," except that the time of burning is four minutes.

As smoke producers, smoke candles have about one-half of the efficiency of smoke grenades, but they have practically no incendiary effect. They are portable and are designed for use by infantry in active operations. They are useful for blinding machine guns, for screening local attacks, and for simulating gas attacks. They may be used for concealing concentrations of guns or troops, battery positions or areas, or putting up a smoke barrage along the flank of an attack.

An operation with these candles should be carried out by a squad under the direction of a competent gas officer who makes wind observations and decides whether the candles may be used to advantage. At least 500 candles should be used for even a small operation. The number started at the beginning should make a dense cloud, and this can then be reinforced by fresh generators as required.

The number of smoke grenades or smoke candles required to form an effective screen depends upon all the considerations enumerated under "Smoke Screens." No definite rules can be laid down as to the exact quantities of smoke producing substances required to form a screen, as conditions vary greatly.

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Three-inch Stokes Mortar Smoke Bombs.—The 3-inch Stokes mortar bomb places in the hands of the infantry a means of forming smoke barrages at greater ranges than is possible with the rifle grenade. The 3-inch and 4-inch Stokes mortar bombs compare approximately as follows:

	Amount of W. P.	Maximum Range
3" Smoke Bomb.....	about 2.5 lbs.	1800 yards
4" Smoke Bomb.....	about 7.0 lbs.	1160 yards

The use of the 3-inch Stokes mortar smoke bomb will economize on guns if they are used wherever possible, as they will be used from the front line trenches and will have a maximum range of approximately 1,800 yards. The fact that these smoke bombs will be entirely under the control of the infantry operates as an additional advantage in that smoke barrages will at all times be available to cover the retirement of daylight raiding parties.

It will also be possible to carry the mortars forward together with a supply of the smoke bombs to provide smoke screens in the large stages of an infantry advance.

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CHAPTER IX

Persistencies of Gases, Methods of Projection, Employment of Chemical Substances in Tactics, Phosgene, Chlorpicrin, Mustard Gas, Brombenzyl-Cyanide, Special Application of the Various Groups.

When ground has been evacuated in consequence of a mustard gas bombardment, the length of time which must elapse before it can be occupied should be foretold as accurately as possible. Tremendous advantage may be gained by being able to estimate this period more accurately than can the enemy.

The rate of evaporation of a liquid from the ground is increased by increased wind velocity and especially by increased temperature. Mustard gas in the woods or in calm weather, will persist much longer than in the open or in windy weather. It will last longer on cold ground than on hot ground. However, during a cold night, an infected area may perhaps be traversed with little danger, provided the feet are properly protected, whereas the following morning, after the sun has warmed the ground, enough vapor may be given off into the air as a result of the increased evaporation to gas severely any one traversing the area.

Moisture produces (though very slowly) the chemical decomposition of mustard gas so that it will persist for a shorter time in moist soil than in dry soil of equal temperature. If the mustard gas

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liquid is dispersed in very fine droplets, it will disappear much more rapidly than when splashed in large drops upon the ground.

The table on the following page will serve to give a rough idea of the persistency which may be expected from gases as spread by shell of the usual types.

The persistency of mustard gas on the ground is diminished by heavy rain, which washes it away, or by sunshine or strong wind which hastens its evaporation. Sunshine, on the morning after a bombardment, may produce a dangerous concentration of gas, where no marked effect had been noticed during the night. The wind limits for mustard gas are from calm to 12 miles per hour; the lower the velocity of wind, the greater the local concentration of gas. Variations may be expected according to the principles above discussed. In the case especially of chlorpicrin, the air may have become safely free from the gas while the ground still contains enough to make it dangerous to entrench in it.

Chemical substances may be projected in military operations as follows: (a) In form of cloud gas discharged from gas cylinders. (b) In steel bombs fired from Livens Projectors. (c) In steel bombs fired from 4-inch Stokes mortars. In the American Expeditionary Forces the three methods mentioned above were used by Gas Troops for projecting gas. (d) In shells of various caliber fired from Artillery weapons. (e) In grenades (including smoke grenades), thrown by hand or rifle. (f) In form of smoke bombs thrown by 3-inch Stokes mortars. (g) In form of smoke candles set off in

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THE PERSISTENCY OF GASES

Gas		Persistence			Remarks
Name	Class	Symbol	In Open	In Woods	
Vincennite Vitrite Collongite (Phosgene)	Non Persistent	V.N. C. C. C. G.	10 minutes	3 hours	These gases are very volatile, they are vaporized entirely at the moment of explosion, forming a cloud, capable of giving deadly effects, but which loses, more or less rapidly, its effectiveness by dilution and dispersion into the atmosphere.
Aquinite (Chlorpicrin) and (Opacite) (Stannic Chloride) Aquinite Chlorpicrin Martonite (Bromacetone)	Moderately Persistent	N. C. P. S. B. A.	3 hours	12 hours	These gases, having moderately high boiling points, are only partially vaporized at the moment of explosion. The cloud formed upon explosion is generally not deadly, but it immediately gives penetrative lachrymatory, or irritant effects. The majority of the "Gas" contents of the shell is pulverized and projected in the form of a spray or fog which slowly settles on the ground and continues to give off vapors which prolong the action of the initial cloud.
Yperite (Mustard Gas) Camite (Brom Benzyl Cyanide)	Highly Persistent	H. S. C. A.	3 days	7 days	These gases, having a very high boiling point, are but little vaporized at the moment of explosion. A small portion of the contents of the shell is atomized and gives immediate effect, but by far the greater part is projected on the ground in the form of droplets which slowly vaporize and continue the action of the initial cloud.

The above figures on time of persistency are approximate only and for calm weather. Persistency is dependent to a large extent on temperature, wind velocity, and amount of gas liberated, especially in woods or other more or less closed places. High temperatures and wind velocities decrease persistency and low temperatures and wind velocities increase it.

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place. The last three forms are used by Infantry. (h) In form of incendiary and smoke bombs dropped from airplanes by the Air Service.

Meteorological, topographical, and other pertinent conditions being favorable to the use of gas in a given tactical situation the kind of gas to be employed in the tactical operation depends on persistency and nature of the effect of the gas, whether temporary, permanent or delayed. It is relatively unimportant to distinguish between the various physiological effects which may be included under the above headings. For evample, it is not of great consequence in planning an operation to distinguish between temporary casualties produced by coughing, by vomiting, or by lachrymation. It is important to know only whether the effects will be produced rapidly and whether they will persist for a long time. Moreover, it is unimportant to distinguish between substances on the one hand which produce bad burns, and those on the other hand which produce lung lesions. Both can be used to decrease the effective strength of the enemy.

The following table, considered in connection with the preceding table, illustrates the tactical possibilities of the substances described.

PERSISTENCE		NATURE OF CASUALTY PRODUCED		
		Temporary	*Permanent*	*Delayed*
Group I.	Low	Diphenyl-chlorarsine.	Phosgene-Chlorine	.....
Group II.	Moderate	.....	Chlorpicrin	.....
Group III.	High	Brombenzyl cyanide and other lachrymators (tear producers).	.....	Mustard Gas

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Smoke, although used for screening purposes rather than for toxic effect, falls within the scope of Chemical Warfare, and may be considered as a separate group. This group includes tin tetrachloride, silicon tetrachloride, titanium tetrachloride, and white phosphorus. The tetrachlorides are liquids, non-poisonous, but producing a dense smoke, principally useful in ranging. Being liquids, shells filled with them have the same ballistic characteristics as gas. White phosphorus is a solid which, upon bursting in air, burns with a dense white smoke. It is useful for smoke screens. Phosphorus burns make ugly wounds.

The chemical substances described may be employed in support of troops acting either offensively or defensively. Offensively they must be employed for the purpose of assisting in gaining and maintaining that fire superiority necessary for the infantry to advance. This may be accomplished by:

Producing casualties among the enemy personnel directly employed in the delivery of fire.

Limiting the maneuvering ability of hostile forces by forbidding or rendering impracticable the use by them of certain areas heavily gassed .

Producing casualties among hostile reserves, thereby reducing the strength of a counter-attack.

Reducing the effectiveness of hostile fire by compelling enemy personnel to wear gas masks.

Reducing effectiveness of hostile fire by establishment of a smoke screen, thus preventing aimed fire and observation of effect of fire by the enemy.

By deceiving the enemy regarding the place or direction of the attack.

Reducing the effectiveness of hostile fire by lower-

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ing the morale of the troops continuously exposed to the effects of gas.

Gas in offensive operations may be used in preparation for the attack or during the attack. Troops on the defensive may employ gas to prevent the enemy gaining or maintaining the fire superiority necessary to advance. Troops on the passive defense have a wide field of use for gas because none of the restrictions which exist when gas is used to assist troops acting offensively are imposed. When, however, troops are acting on the defensive awaiting a favorable opportunity to attack, gases must be so employed that they shall not interfere when an otherwise favorable opportunity is presented to resume the offensive.

In a withdrawal or in a retreat the employment of chemical substances is especially applicable as they may then be freely used without fear of deleterious effect on our own troops. Gases may be used under such tactical situations to reduce casualties among friendly troops, by screening movements of friendly troops and to prevent or delay pursuit, by denying hostile troops the use of landmarks on which to guide through, causing them to advance through smoke clouds and thereby favoring loss of direction by enemy units and their mixing in the advance, and by causing casualties among pursuing troops by heavily gassing areas included in their line of advance.

The most effective gas against hostile personnel may, under a given tactical situation, be one against which the enemy has no or only indifferent means of defense, even though such a gas may be of low persistence or have only a temporary effect on hos-

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tile personnel. For this reason it is necessary to know what are the limitations of the means of defense against gas available for use by the enemy. Assuming the enemy means of defense are efficient against all available gases, the kinds of gases used in any tactical situation depends upon time available before friendly troops, under the plan of operation, will probably occupy the area gassed, as well as upon meteorological and topographical conditions and the persistency and effect of available gases.

Special application of the various groups of chemical substances (phosgene, chlorpicrin, mustard gas, brombenzyl-cyanide) are numerous and most important. The following observations and applications are worthy of careful notation:

Phosgene.—During the entire period of preparation for an attack, as well as in the earlier stages of preparation, when mustard gas is being used, put over phosgene in sudden two-minute bursts of artillery fire, at repeated intervals of from 8 to 12 hours, upon strong points, concentration areas, woods and ravines, and upon groups of trenches and dugouts, to kill those whose masks are worn out or those who, through recklessness or carelessness, have removed their masks.

On targets, distant 1900 meters or more, use artillery to carry out the tactics outlined in paragraph above. Whenever possible, the area within 1900 meters of our line should be taken care of by Gas Troops, using cylinders for cloud gas, when the wind is favorable, and projectors and 4-inch Stokes mortars, all of which can produce much higher gas concentration than artillery.

When the wind is favorable (blowing toward the

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enemy), launch against the entire front to be attacked, and for miles along the front not to be attacked, heavy phosgene gas attacks by all methods, including cloud gas from cylinders. If the wind is unfavorable, phosgene may still be used with artillery, projectors and Stokes mortars by simply reducing the amounts put over in accordance with the tables of safe distances. When immediate neutralization is required, phosgene is generally preferable on account of its immediate effect.

Gas troops with Stokes mortars, projectors and cylinders are trained to keep up with infantry reserves, whence they can be directed to the support of attacks of strong points, machine gun nests and enemy troops concentrating for counter-attacks, by projection of phosgene, or by projection of phosphorus for smoke screens. They are also equipped to fire upon hostile personnel with thermite, phosphorus and incendiary bombs and drums thrown from mortars and projectors.

With unfavorable winds phosgene and chlorpicrin may be used by artillery, and by Gas Troops, employing projectors and 4-inch Stokes mortars, which should direct their fire just beyond the nearest enemy masses so as to let the gas drift back over them. The amount of gas must be reduced, but not necessarily to the amounts given as safe under rules for firing of gas by artillery. Some chances must be taken with our own gas even to the extent of an occasional casualty. With the new mask, giving perfect vision, accidental casualties should be rare.

RS. *Chlorpicrin* is stopped by the mask much less readily than phosgene, and in the high concentrations attainable in projector attacks heavy casualties

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may be expected. It is moderately persistent, and its value in artillery shell is due to this fact and to its lachrymatory power. From 3 to 12 hours should be allowed where troops are to cross the infected area, depending upon whether the area is open or wooded.

Mustard Gas.—The characteristics which make mustard gas so valuable are very little odor, absence of immediate effect, effectiveness in low concentrations and its persistence. The following directions and observations are most important:

(a) Use for harassing fire against batteries, strong points, woods, cross roads and enemy concentrations everywhere at all times prior to attacking. (See c. d. and e.)

(b) As it affects eyes, lungs, body and food, and persists for days, it wears down the enemy morale and vigor by forcing constant wearing of the mask and the necessity of always taking other extensive precautions.

(c) In the open it may be used when the weather is clear and warm up to 3 days before an attack.

(d) When weather is cloudy and warm, add 1 day to (c).

(e) When weather is cold and especially cloudy, allow 4 to 7 days.

(f) In thick woods or brush heavily bombarded with mustard gas, allow 5 days in warm weather and 7 days in cold weather before attacking through them, except under special conditions.

(g) An infected area may be crossed more safely when the ground is cold, as during the night. The above intervals may be reduced if this precaution is taken.

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(h) Continue neutralizing and harassing fire against strong points, battery positions, cross roads and any possible concentration points during the entire battle, in accordance with the schedules given in (c), (d), (e), and (f). The flanks, where no attack is to be made by our troops, should be kept smothered with mustard gas to prevent the possibility of a flank counter-attack.

(i) It may prove possible in the future to change the burst of mustard gas shell so as to diminish the persistency, allowing earlier attack following its use, and producing greater concentrations.

(j) When the enemy succeeds in halting our attack at any point, use mustard gas in accordance with the schedules given under (e) and (f), and in the intervening period up to the moment of the attack, pour in phosgene with both artillery and Gas Troops. When the wind is unfavorable, i.e., blowing toward our troops, merely reduce the amounts sent over.

(k) Gas used as explained under (j) is a valuable weapon to break up resistance in general, and is especially valuable for use against enemy troops concentrated for counter-attacks.

(l) The use of mustard gas must be continuous on woods, ravines, roads, villages, railroads, and any other places where enemy troops can concentrate or where they must move. Fields that the enemy may cross should be thoroughly gassed.

(m) Used in this way, it should be very effective in inflicting serious losses from burns, even if the mask fully protects.

(n) Mustard gas can be used in the offensive without endangering our troops, beyond or to the

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flanks of an objective. When the objective is a limited one, always allow clearance of one mile as a safety factor in case the wind should prove adverse.

(o) Bombardments with mustard gas are best carried out at night, when the atmospheric conditions are most likely to be favorable, and when, owing to the difficulty of seeing while wearing a respirator, the maximum amount of interference with movement is caused. In addition, the evacuation of shelled areas is most difficult at night.

C.A. **Brombenzylcyanide** (lachrymator).—This is used anywhere to force immediate wearing of the mask. It is a powerful lachrymator, and very persistent, but not poisonous unless one is very close to a bursting shell. It is two to three times as persistent as chlorpicrin.

It is useful to save mustard gas, phosgene and chlorpicrin, and still harass the enemy by forcing him to wear masks. For this purpose it is many times more effective than phosgene and chlorpicrin.

It is especially useful against active combatants, as few guns are necessary to produce the desired effect.

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CHAPTER X

Use of Gas by Gas Troops, Organization of Gas Regiment, Duties of Regimental Officers, Duties of Company Officers, Stokes Mortars and Bombs, Smoke Bombs, Propellants and Fuses, Livens Material, Cloud Gas Apparatus, General Procedure in Gas Operations.

The development of the use of chemicals in modern warfare has resulted not only in the introduction of new weapons and methods, but also in the employment of gas troops. The experience gained is sufficient to fix the field in which such troops can operate most effectively and point out the general principles underlying the most advantageous use of the weapons with which they are armed. Because of the highly technical nature of this service, troops engaged in it should be specially trained and equipped. Because of the hard physical labor required, the personnel should be of specially good physique.

The chemicals used in warfare may be divided into four general classes. One class comprises chemicals which, when breathed or brought into contact with the human body, produce fatal or incapacitating results. Another comprises those used for purposes of deception or concealment. The third comprises incendiary agents. The fourth comprises high explosives. The use of these ma-

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terials has brought about the perfecting of three new weapons, the Stokes trench mortar, the Livens projector and the gas cylinder. The two former are used for the projection of bombs or drums containing chemicals. The projectile for Stokes trench mortars is usually called a bomb, while that of the Livens projector is usually called a drum. The cylinder is used exclusively for the projection of gas clouds. Stokes mortar bombs may contain any of the four classes of chemical agents, but in general the Livens projector is limited to agents of the first and fourth classes only.

Gas troops are Army troops, usually one regiment per Army. Their battalions and companies are attached to Corps and Divisions as required by the nature of the operations contemplated. As a rule, a unit smaller than a company should never be attached to a Division, nor a unit smaller than a battalion to any Army Corps. Gas regiments as now authorized consist of six battalions of three companies each, with a total of 210 officers and 4,873 enlisted men. Of the six battalions five are combat battalions and one a replacement battalion. This is made necessary by the technical nature of the work, and the necessity of replacing casualties with trained personnel.

The organization of the Regimental Headquarters follows that of the Special Engineer Regiments, except that a lieutenant colonel is provided for each two battalions and an additional first lieutenant is authorized as assistant adjutant. The enlisted personnel of 39 is sufficient to handle only the routine administration work. In order to maintain the necessary transportation to take care of the regi-

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ment's service of supply, it is necessary to call upon the battalions and companies for assistance. In normal operations, from 200 to 250 men are required for transportation and service of supply. By far the best results are obtained by directing the use of transportation from regimental headquarters.

Adjutant and Personnel Officer.—These duties follow closely those of similar positions in a normal regiment.

Chemical Adviser and Intelligence Officer should have: (1) An exact knowledge of the characteristics and proper use of gases in gas warfare; and such knowledge as will enable him to forecast with fair accuracy the probable importance of suggested developments. (2) An accurate knowledge of the varying front line conditions; of the past and present operations of Gas Troops, and of the plans and possibilities for future operations.

The duties of this officer are, to obtain, properly file, and transmit information, particularly with a view of keeping the Gas Troops informed of the results obtained in Gas Warfare, and of keeping the technical and supply divisions informed of the needs of the Gas Troops. Since all intelligence matters concerning operations pass through the hands of the Chemical Adviser and Intelligence Officer, certain other duties concerning the conduct of operations and reports thereon, have been added to the foregoing.

The Chemical Adviser and Intelligence Officer should, therefore: (1) Procure, digest and file such scientific and technical papers and publications as are of possible practical value to the regiment. (2) Keep in touch with new developments in Of-

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fense Gas Warfare, with changes in offense gas weapons or material, and pass on useful information regarding the same. (3) Forecast all the necessary ordnance supplies for the regiment. Investigate complaints regarding the technical supplies received and suggest any necessary improvements. (4) Transfer all suggestions of value regarding possible improvement of weapons or methods in Gas Warfare to the Commanding Officer concerned or to the Offense Division, Headquarters, Chemical Warfare Service, for investigation. (5) Render all possible assistance (consistent with other duties) to the Offense Division in its investigations. (6) Obtain information from army regarding position of our advance line and keep regimental headquarters map up to date. (7) Obtain daily summaries of intelligence published by the army and the various corps and divisions with whom the regiment is operating. Study any intelligence regarding the enemy positions or activity that may prove useful in pending operations, and furnish same to all commanding officers concerned. (8) Have the location of all gas battalion or company headquarters and dumps indicated on the regimental headquarters map. Be conversant with the various means available for inter-communication between all regimental units. (9) Have on hand a list showing the location of all corps and division headquarters on the front where the regiment is operating and have same plotted on the regimental headquarters map. (10) Have suitable road maps of the advance zone, showing first class "up" and "down" traffic routes; also have traffic maps of lines of communication. (11) Procure and keep on hand a suf-

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ficient supply of suitable maps for all present and pending operations, and be prepared to make at short notice maps concerning any projects on hand. (12) Have on hand a relief map of the front on which the regiment is operating. (13) Obtain information as to present plans of battalion and company commanders and be prepared to suggest new operations on which those units can be profitably employed. (14) Take charge of all secret correspondence "inward" and "outward," regarding the employment of the regiment and its movements or future operations. (15) Receive all daily progress and operation reports from battalions and companies, check same, and be conversant at all times with their contents. (16) Collect and pass on to officers concerned intelligence on results of operations by the regiment and the gas troops. (17) Compile and distribute a regimental daily bulletin containing information of importance or interest. (18) Be thoroughly conversant with all Gas Defense measures, and be able to advise concerning any special precautions necessary to be taken by Gas Troops for protecting them against their own gas. (19) Advise the Regimental Supply Officer as to the location of important forward Gas Dumps and the storage of material in them. (20) Obtain and supply to all officers concerned such meteorological data as may be of service.

Regimental Supply Officer.—The duties of this officer are as follows: (a) To anticipate the supplies required by the Regiment and deliver them to mobile dumps easily accessible to the companies and battalions. These mobile points should move as the units move so that the amount of truck trans-

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portation is minimized. (b) To control all motor and animal transportation.

In connection with motor transportation, the Regimental Supply Officer is to maintain a suitable and sufficient personnel to operate and maintain all trucks, touring cars and side-cars assigned to the organizations.

The Regimental Supply Officer cares for the replacement of all animals injured or taken sick, recommends personnel to handle them and arranges for periodic inspection as a check on their care, use and proper shoeing. He also assists the companies and battalions in arranging for any rail shipment they may be required to make, and takes care of any construction work and any other miscellaneous work which obviously is not a part of the duties of the other staff officers. He works with the Battalion Supply Officers, and through them with the Company Supply Officers, and sees that each is acquainted with and performs his full duty.

Master Engineers.—The duties of the Master Engineers are as follows:

Chemical Assistant.—This assistant operates directly under the orders of the Regimental Chemical Adviser and Intelligence Officer and assists him in every way in chemical matters.

Map and Intelligence Assistant.—This assistant is charged, under the Regimental Chemical Adviser and Intelligence Officer, with maintaining complete map files and all intelligence covering operations.

Training Assistant.—This assistant is charged, under the Regimental Chemical Adviser and Intelli-

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gence Officer, with the coördinating and assisting in the training and instruction.

Transportation Assistant.—This assistant is charged, under the Regimental Supply Officer, with looking after the work in the transportation division and includes operation and maintenance of all motor vehicles.

Supply Assistant.—This assistant functions directly under the Regimental Supply Officer.

Special Equipment Assistant.—This assistant is charged, under the Regimental Supply Officer, with keeping fully informed on Special Equipment situation as regards manufacture, supply in all depots, and supply of troops operating on the lines.

Construction Assistant.—This assistant functions directly under the Regimental Supply Officer and is available for all construction work. He must be a man capable of handling men on general construction work.

Military Assistant.—This assistant functions under the Regimental Adjutant. He is available for the training of replacements, for taking charge of or assisting in special technical training.

The duties of the Battalion Staff Officers, while following generally those of similar positions in the normal battalion, also parallel to a great extent the duties of the corresponding regimental positions outlined above. The duties of Battalion Staff Officers are, furthermore, made difficult by the necessity of controlling and supplying units operating over an extended front and in small detachments.

The company is organized into a headquarters section and four platoons. The headquarters sec-

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tion takes care of the normal administration of the company, thus leaving the platoons free for actual fighting. Each platoon is organized into two sections and each section consists of two Stokes mortar gun-teams with a carrying party. This gives sixteen mortars per company. All platoons are trained in projector and cylinder work.

The platoon is the working unit of the regiment. This is specially true in a war of movement. It is rarely necessary to install more than four guns in conjunction with the advances or attacks of an infantry regiment, and when it is necessary for one company to operate on a divisional front, such an arrangement permits covering the front not only at the start of the operation but also enables the platoons to follow the infantry regiments to which they are attached and give assistance as the attack develops.

Each platoon is organized as an independent unit insofar as concerns its independent functioning in action. This calls for the assignment of a cook and the supply of the necessary cooking equipment. Each company should be supplied with four small field ranges in addition to the regular rolling kitchen.

The commissioned personnel of the company consists of nine officers, two of whom are captains. The additional commissioned personnel is made necessary by the character of the work and the entire number is necessary to insure proper functioning.

It is impossible for one officer to properly command the company, care for his men and at the same time carry on the extensive liaison that is necessary in the functioning of a gas company. The

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addition of the second captain (the Second in Command), fills a need and has proved to be a necessity in action.

The Company Commander (1) actually commands the company and carries the full responsibility of the position. (2) He directs and supervises the training of his company. (3) He personally directs disciplinary actions and is responsible for the discipline of the company. (4) It is his duty to see that all officers under his command have the requisite technical knowledge and training. (5) It is his duty to see that all officers perform their full duty and actually accept the full responsibilities of their respective duties. (6) He personally examines, verifies and signs all reports and letters connected with the company work. (7) He makes inspections from time to time to ascertain whether the company is properly clothed and equipped and whether the equipment is up to the standard set. (8) He designates the approximate location of advanced company and platoon headquarters and dumps. (9) He makes the necessary forecasts covering amounts and kinds of ammunition and supplies needed. (10) He issues the necessary orders to cover reconnaissances and operations. (11) He carries on and maintains liaison with Division and Brigade Headquarters. (12) He keeps fully informed of the tactical situation, the plans of the various Commanders and makes the necessary recommendations covering the correct and best tactical use of the Company. (13) He assists the Platoon and Section Leaders in perfecting and maintaining liaison with Regimental and Battalion Headquarters. (14) He obtains informa-

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tion as to enemy troop concentrations and sends data to Platoon Leaders as to possible targets. (15) He arranges necessary system of runners and necessary passage of messages between the units of his command and units with which he may be operating.

The Second in Command (1) keeps himself prepared to take up the duties and responsibilities of the Company Commander at any time. (2) He sees that all orders and instructions are complied with and routine matters carried out. (3) He supervises the care of the men, their training and equipment, and is responsible for the company at all times ready for immediate service. (4) He carries on the interior administration of the company. (5) He establishes and arranges forward company billets and dumps and sees that necessary and proper guards are established. (6) He must see that proper messing arrangements are made and that at all times the men are supplied with proper food. (7) He personally checks up the ration issue and sees that rations are properly used. (8) He supervises the supply of munitions as given by forecasts of the Company Commander. (9) He keeps himself fully informed of the existing tactical situation of all company units. (10) He is the Company Gas Officer and is responsible for the gas discipline of the company.

The Company Supply Officer is responsible for supplies, transportation and records. All supplies (quartermaster, ordnance, signal, engineer, technical supplies and rations) must be requisitioned through the Battalion Supply Officer. When the company is operating independently, rations are

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drawn from the units to which the company is attached. Each corporal is held personally responsible for the condition of his men's equipment and must report once each week to his platoon commander who reports to the Company Supply Officer. Company Supply Officers make a weekly report to the Battalion Supply Officer, showing their exact present needs and their immediate future needs.

The minimum amount of transportation required to perform the operation in hand and amount of time required must be estimated. Particular attention should be paid to the type of transportation best adapted to the operation; e. g., rail, truck, animal or narrow gauge. This information should be conveyed to the Battalion Supply Officer requesting that he furnish the transportation. Careful written orders with map should be given the non-commissioned officer in charge of the transportation. These should state the time the transportation is to leave, the cargo to be carried, the route to be followed, the destination, and to whom the material is to be delivered. The non-commissioned officer acting as convoy must check the list of material delivered and report the same to the Company Supply Officer, and he in turn to the Company Commander. All company transportation is under his immediate control as regards operation. The Company Supply Officer must know at all times the location of all trucks assigned to his company, their condition, and the work upon which they are engaged. All unserviceable trucks must be reported immediately to the Regimental Headquarters for disposition. Transportation is not to be overhauled by the companies.

Careful records must be kept by the Company

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Supply Officer showing the disposition of all material and equipment issued to his company. These records should be kept so that at any time he can render a report showing the amount of loss of any particular supplies by his company.

The Platoon Leader (1) must fight his platoon along correct tactical lines. (2) He must personally see that his platoon is properly clothed, equipped, fed and housed. (3) He must carry on and maintain proper liaison with company and units to which attached. (4) He must make necessary local reconnaissances and select suitable emplacements with maximum possible protection. (5) He must actually direct the work of his platoon and personally check up the construction of the emplacement, sighting and elevations of guns, make necessary examination of guns and ammunition and all other matters pertaining to the operation. (6) He must know each man in his platoon by name and make a study of his abilities. (7) He makes out accurately, necessary reports and forwards them to the Company Commander. (8) He must keep his platoon prepared for service at any time. (9) He must personally take charge of the men's technical training under the supervision of the Company Commander and Second in Command. (10) He takes charge of his platoon at all company formations and drills. (11) He, from all his personal knowledge of his men, advises the Company Commander as to the qualifications and shortcomings of his men and also recommends promotions. (12) He personally sees that all orders pertaining to his platoon are carried out.

Four-inch Stokes Material.—The 4-inch Stokes

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mortar is, within its range, a particularly suitable weapon for gas projectiles, owing to its comparative accuracy and rapid rate of fire, and to the quantity of gas which each bomb contains (about 2 1/2 quarts). The comparative silence and absence of flash on discharge are useful when surprise is desired, and very heavy concentrations of gas can be established at the target in a short period of time. This mortar is quickly placed in position. It can be used for several purposes and it is sufficiently mobile to be carried forward with infantry for employment from advanced positions. It consists of a steel barrel connected by a double collar to a tubular steel stand which is fitted with elevating and traversing gears. The breech piece of the mortar rests on a base plate with socket. The mounting admits of the mortar being traversed 2 1/2°, traversing to the right or left of the central line without moving the legs of the stand or the base plate. The rate of fire by day for a short period is 20 rounds per minute, although with a well trained detachment a higher rate can be obtained for short bursts, not exceeding one or two minutes. At night 12 rounds per minute is all that can be expected.

Barrel.—This consists of a solid, drawn steel tube, 48″ long, with a smooth bore varying from 4.15″ to 4.20″ in diameter. Two bands are clamped around the barrel near the muzzle to engage the bipod carrying the elevating and traversing devices. In the base of the barrel is screwed a breech piece containing a striker stud or anvil. This anvil has a flat top for firing cartridges and a nipple for firing biscuits.

Stand or Bipod.—This is the gun support and

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carries the elevating and traversing mechanism. It consists of two tubular steel legs with a cross stay and spiked feet to prevent spreading.

Base Plate.—This is an octagonal steel plate with a flanged socket for the reception of the breech piece. The American base plate is similar to the British except that it is round instead of octagonal. Base plates are usually reinforced with heavy oak planking to prevent their displacement when firing.

The weights of the various parts of the mortar are as follows:

Stand	30 lbs.
Barrel	90 lbs.
Base Plate	60 lbs.
Wood sub-base	60 lbs.

The mortars above described are of British manufacture. American mortars are practically identical except for some slight difference of weights.

Stokes Mortar Bombs, as used by Gas Troops, are of four types, gas, thermit, smoke, and ranging. All American bombs are made of wrought iron or steel. All bomb bodies are painted *dirty white,* and when filled have a red band near the top of the body. Two bombs are packed in a box, complete with charges and fuses. The boxes measure approximately 2 feet 2 inches by 7 1/2 inches by 11 1/2 inches.

Light Smoke Bomb.—This is a 16-pound bomb consisting essentially of a steel cartridge container, sheet metal body, and a canister containing red phosphorus. The canister is kept in position and the whole bomb cemented together by a layer of pitch.

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The gaine consists of a .410 cap, a length of Bickford fuse, and a primer which explodes an ophorite charge in the bottom part of the gaine. The cap is fired by a spring striker head, so adjusted that the inertia of the striker is sufficient to compress the spring and fire the cap on discharge. This bomb is fired with a ballistite cartridge which gives a maximum range of 460 yards. For this reason the bomb is seldom used except for training purposes.

Heavy Smoke Bomb.—This is a 25-pound steel bomb, of general construction, and contains 7 1/4 pounds of white phosphorus. It is fired by the British 31-D or 79 fuse.

Incendiary Bomb.—This is similar to the heavy smoke bomb in general construction and takes the same fuses. It weighs 22 pounds and contains 7 pounds of thermit.

Gas Bomb.—There are over fifty different kinds of British gas bombs, different in details of construction and operation. But they may be divided into two general types—old style, fired with E. C. biscuits; and new style, fired with cordite rings and with either pink or blue cartridges.

Ranging Bomb.—This is a bomb partly filled with black powder, to be used for ranging or registering purposes. It may be fitted with either the cartridge container for firing by cordite rings, or with the biscuit container for firing with biscuits. It is little used except for instruction and practice.

American Stokes Bombs.—American bombs have been standardized, differing only in the gaine tube. They all use the same propelling charge and fuse. This will give all bombs uniform range.

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There are three general types of propellants used with the present British Stokes mortar ammunition—E. C. 3 powder, cordite, and ballistite.

British E. C. 3 Powder.—This propellant is used with all British gas ammunition and ranging bombs furnished gas troops. It is usually made up in the form of biscuits containing 400 grains of E. C. 3 powder each. One, two or three biscuits may be used, being placed in what is called the biscuit container which is screwed onto the base of the bomb. When less than three biscuits are used the extra space in the container is filled with felt wads. The biscuits are fired by a .303 cap reinforced with powder and protected from damp by a disc and varnish. Caps should be examined before firing. If they fit loosely in the container they should be removed and new ones substituted, as loose caps often cause misfire.

British Cordite Charges.—This ammunition is used with all thermit and heavy smoke bombs. It consists of a 12-gauge cartridge containing 150 grains of cordite, or ballistite and from one to four rings of 350 grains each. In firing the cordite cartridge is placed in a cartridge container screwed on the base of the bomb, and 1 to 4 rings placed around the cartridge container, depending upon the range desired. The cartridges bear their own strikers, which are protected by a ring. Blunt strikes or anvils turned down to a smaller diameter than the protective ring, are used for firing. The objection to this charge is that it makes a very strong flash and soon dirties the mortar.

Recent ammunition has been furnished with a blue cartridge containing 95 grams of ballistite in

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lieu of the cordite (called pink cartridge) described above. This substitution has been made to reduce the flash of discharge, but has also reduced the range by approximately 10%.

British Ballistite Charge.—The ballistite charge consists of a cartridge containing 350 grains of ballistite primed with gun cotton. It is used only with a light smoke bomb. It is fired by means of a striker clip and a flat anvil similar to that used for the cordite cartridge.

British Mills Pistol Head.—This is used for firing all gas bombs. On discharge, the inertia pellet depresses its spring, releasing the lever, which in turn releases the striker pin. The striker spring being under compression expands and impinges the striker pin against the detonating cap in the end of the gaine tube. This fuse does not operate unless the bomb has sufficient velocity to travel 100 yards.

British Allways or 146 Fuse.—This is a percussion fuse which has also been used with gas bombs. An instantaneous fuse must be used in place of the ordinary time fuse in the bomb. Upon firing, the tape retaining pin is dislodged, allowing the tape to unwind during flight. This action causes the safety bolt to drop out, arming the fuse. Upon impact the steel ball forces down the striker holder, forcing the detonator and igniting the instantaneous fuse. Immediately before firing, the safety pin arm must be withdrawn. On no account should the tape be disturbed. If on withdrawing the safety pin, the tape retaining pin is released, it must be replaced before firing.

31-D Fuse.—This fuse was formerly used on all thermit heavy smoke and ranging bombs. It was

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only an improvised fuse, made by modifying the obsolete No. 31 British artillery fuse, and it is now being supplanted by the No. 79 (Sutton) Mark II fuse. The 30-D fuse consists of two powder trains, set by means of a time scale. On discharge, the set-back pellet fires the cap, which ignites the powder train. This in turn ignites the powder charge which explodes the bursting charge in the bomb.

British Sutton or 79 Fuse.—This fuse is used on all thermit, heavy smoke and ranging bombs. To set the fuse, the indicator mark in line with the auger hole is turned to the graduation required, and the time train in the base of the fuse punctured by means of an auger. The safety pin should not be withdrawn until the moment of firing. This should be done with care, as a fuse cannot be clamped, and any alteration in the setting will cause blinds. On discharge, the set-back pellet fires an explosive cap, which in turn ignites the powder train, and thence the powder in the chamber.

American Trench Mortar Fuse Mark V.—This fuse is a simple time fuse for all 4″ trench mortar bombs where air bursts are desired. It is essentially a copy of the British No. 79, Mark II.

American Trench Mortar Fuse, Mark XI.—This is an "Allways" percussion fuse and is to be used on all American 4″ trench mortar bombs for contact bursts. The safety pin is withdrawn just before firing. On shock of discharge, the pellet sets back, allowing the safety fork to fly out, thus arming the fuse. On impact, the striker fires the cap, igniting the powder charge and thus exploding the bursting charge in the bomb.

The Livens Projector is a very simple form of

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mortar which projects quantities of gas, incendiary, or high explosive substances, by means of cylindrical drums rounded at both ends. This projector is a smooth-bore steel tube closed and rounded at one end and open at the other, having an internal diameter of 8″. Projectors are made in various lengths. The several types of the Livens Projectors are as follows:

Mark No. 1.	Length	2′9″
	Thickness	3/8″
	Weight	105 lbs.
	Material	Solid drawn steel.
Mark No. 3.	Length	2′6″
	Thickness	1/4″
	Weight	65 lbs.
	Material	Lap welded mild steel.
Mark No. 9.	Length	4′6″
	Thickness	3/8″
	Weight	150 lbs.
	Material	Solid drawn steel.

American Projectors.—The American projectors are copied from the British. They are made in two sizes, Mark I (barrel length 2′9″, weight approximately 100 pounds), and Mark II (barrel length 4′, weight 150 pounds). All projectors have an internal diameter of 8″. The wire wrapping of projectors gives greater strength for euqal weight and thus allows for a greater chamber pressure; hence, a larger propellant charge may be used, thereby insuring greater range. Increased portability can also be obtained without decrease of range.

The Livens projector base plate is of pressed steel about 1/4″ thick and 18″ in diameter. It weighs about 30 pounds. It is used as a backing to pre-

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vent the projector from burying itself in the ground on recoil. There is also a 12″ base plate, the only difference being that the crimped edges are flattened instead of slanting as in the 18″.

The Livens Drums are of three classes, gas, incendiary and the high explosive. All drums are made of mild steel pipe with ends nosed or spun in. They are 21″ in length and have an outside diameter of 7-11/16″. There is a central tube running the length of the drum welded in to the drum at both ends.

In the latest designs of the gas drum the internal diameter of this tube is slightly more than 1″. These drums are filled through holes bored in this tube about 2″ from the end opposite the fuse socket. Below these filling holes the central tube is sealed by a steel plug welded in place. After filling, the drum is sealed by screwing a taper plug in the filling end. The incendiary drum is similar to the gas, the only difference being in the size of the central tube and the method of filling. This drum is filled from the ouside through a hole about 2″ in diameter, cut in the shoulder of the drum at the fuse end, and closed by a screwed plug. The high explosive drum is the same as the incendiary in construction.

Gaine Tube.—This is a copper tube containing the bursting charge of the drum. In the gas drum this tube is about 17″ long and .875″ wide, while in the incendiary its length is 19.3″ and width 1.12″. The bursting charge consists of 60 grams (about 2 ounces) of T.N.T. for the gas drum, and 2 ounces of ophorite for the incendiary.

The priming system used in all Livens drums

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consists of a .410 pistol cap; a 22 second Bickford time fuse, 10″ in length; and a No. 8 commercial detonator loaded with fulminate of mercury to detonate the bursting charge. The detonator is attached to one end of the Bickford and the pistol cap to the other; the whole is then inserted in a thin brass casing which in turn is placed in the gaine tube. The pistol cap is fired by means of a device known as a Livens or Mills fuse. The time of burning of this fuse may be varied by cutting off part of the Bickford and crimping on a new detonator at the desired length. This practice is not satisfactory for the reason that in the field it is difficult to make a moisture-proof joint between the detonator and the Bickford fuse. An "Allways" time and percussion fuse has been developed in the United States for the several types of Livens drums.

Propelling charges are contained in a cylindrical tin box divided into one central compartment and six radial compartments. One compartment contains 12 ounces of cordite, inserted into which is an electric fuse and 4 ounces of black powder a priming charge. The charge is made up of small bags containing various amounts of U. S. smokeless powder. Range variations are obtained by varying the amount of powder in the charge box. The top of the tin container is a stamped steel plate 11/64″ thick. The flanges of this plate overlap the sides of the charge box. On discharge this plate is forced out against the sides of the projector and serves as a gas check.

Electric Fuses.—The British electric fuse used to ignite the cordite propelling charges is known as the Mark III, No. 14. In this fuse a fine platinum

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iridium wire extends between two copper terminals, projecting from a hard rubber casing. Around this wire is wound a small piece of guncotton, and a charge of 2.25 grams of black powder which is set off by the guncotton, and in turn explodes the black powder in the bag surrounding the fuse and hence the cordite propelling charge. The wire has a resistance when cold of 1.06 ohms, and 2.6 ohms on fusion. A current of 0.9 amperes is required to fuse the wire and this amount must be supplied in order to be certain of setting off the guncotton. The American electric primer is a copy of the British No. 14 fuse.

Exploder.—What is known as an exploder for Livens projectors is a small plunger driven, series wound dynamo. The Mark V is the one now used. It should fire a fuse through 100 to 130 ohms resistance. Before being taken up to the front for use, the exploder should always be tested to find the actual resistance through which it fires. This is done by connecting it up in series with a resistance box and a 1/4" gap, across which a bridge of platinum iridium wire of the same nature and dimensions as that in an electric fuse is placed. The tested resistance should equal the sum of the resistance of the main leads, the leads between the guns, and the fuses, plus an allowance for resistance of joints, inequality of fuses and safety. This "factor of safety" is taken 25-33%. Mark V should never be used to fire more than 20 guns.

The fuses used with the Livens drums are of two types, both being time fuses. The Mills pistol head is the same as that used on the Stokes gas bomb. On discharge the inertia pellet is forced back, re-

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leasing the lever, which in turn releases the striker, and detonates the cap in the gaine.

The Livens head is the fuse now commonly used. It consists of a small inertia pellet, held in place by a thin wire. On discharge the inertia pellet is forced back, shearing the wire and detonating the cap. The object of the shear wire is to prevent accidents from shorts. If the velocity of discharge is below a certain value, the wire does not shear and the cap is not detonated.

Whenever installing the projectors a "V" shaped trench is dug about 3'6" wide, 1'9" deep, and 30' long, perpendicular to the line of fire. The projectors are set at an angle of elevation of 45 degrees by means of a clinometer, and aligned by means of a compass. It is generally not necessary to set each gun separately. If one gun is carefully set, several may be aligned from it, with sufficient accuracy. Projectors are generally dug in, in batteries of 20 each; the various batteries of an emplacement being scattered as the conditions of terrain and cover necessitate.

Early in the European war cylinders containing about seventy (70) pounds of liquefied gas were used by both sides for cloud gas, or gas wave attacks. The cylinder used was about 3'9" in height and 8 1/2" in diameter, similar in all respects to the common Co_2 cylinder. The siphon tube, about 3/4" in diameter, extended from a valve at the top of the cylinder nearly to the bottom. The pressure of the gas forced the liquid up this siphon tube through the valve and out into the atmosphere through a parapet pipe, where it vaporized.

The cylinders were placed far forward in the

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trench system, usually in sets of fours, connected by rubber hose to a four-way connection and single parapet pipe. At first, cylinders were used in about the ratio of 1 per meter of front on which the attack took place. More recently 3 per two meters, or even 2 per meter were used. This was accomplished where the width of the trench permitted of double banking. The cylinders weighed, when full, about 140 pounds each.

After a close study of the tactical situation, enemy concentrations, the terrain, and time allowed, the Company Commander decides upon his plan of observations. He then prepares a project which he submits to the Chief of Staff of the division. The project generally covers the following points: (1) Map reference. (2) Object of proposed operation. (3) Emplacements and target. (4) Location of billets desired. (5) Assistance or material needed from Division (transport, carrying parties, etc.). (6) Safety precautions to be taken by units holding line. (7) Wind limits, with map, and (8) Estimate of time required for installation.

On approval of his project the company commander gives detailed instructions to his platoon commanders, assigning them definite duties. These instructions should be given in conference, and confirmed in writing.

All gas officers commanding units assigned to support infantry units will immediately report to the commanding officer of such infantry unit, prepared to submit recommendations regarding the employment of their gas troops. After reporting to the infantry commander each comes directly under his orders and is directly responsible to him for the

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proper conduct of his command, in accordance with the orders issued by such infantry commander. Until he is relieved by the latter he is subject only to his orders, superior commanding officers of gas troops having no authority to issue orders to him affecting the employment of his troops.

Commanding officers of all gas troops in assigning units under competent orders, to operate with infantry units, carefully instruct the commanders of such units, in order that they shall fully understand from whom they receive and obey orders and that they are not sent into combat to conduct independent operations.

Platoon leaders make their own detailed arrangements, and assign the tasks in their own platoons. They organize their platoons as required for carrying, digging in, and camouflaging. Their orders specify the approximate emplacements and target. They must in general determine range, changes, and angle of fire. Their plan of operations, with detailed instructions, should be written and submitted to the company commander for check and approval.

As soon as material arrives, the installation is commenced. As a rule all work must be done at night, in absolute darkness, and silently. This means that each man must know his task, and carry it out promptly and carefully. All material sent forward must be complete and ready for use. No necessary item must be omitted.

Work done by gas troops in forward areas must be directed and controlled with the greatest care and caution. The enemy must not be forewarned by sound or sign. The success of the entire operation depends primarily upon surprise. Warning to

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the enemy will result in a heavy shelling of the area, and probably in a withdrawal of the target.

Camouflage is the concealing of all work done in such a manner as to give no sign of activity or change. It must, therefore, conform to the surroundings. It must protect against: (1) Aerial photography, (2) air observation—airplane or balloon, (3) direct observation. It is necessary to consider and provide against new tracks, regularity of lines, production of shadows, and leaving any work uncovered.

Preliminary reconnaissance must include a special study of camouflage requirements, and the report cover the exact kind and amount needed. Natural camouflage is superior if it can be obtained without being itself noticed. The concealment of emplacements must be carefully supervised each morning before leaving. In difficult cases the division camouflage expert may be called on for assistance.

When the installation is nearly completed, the Company Commander issues his operation order. In addition, a company operation order is issued giving the duties of all platoon or section leaders in the operation.

The zero hour is usually set in conference with the Chief of Staff of the Division, as it may be dependent on other operations. If not, the best time to shoot is at night, when the target is most heavily held, or in general when the chances of surprise are greatest.

Liaison.—Experience has demonstrated the great importance of good liaison. It must always be maintained with all units whose operations are in any way dependent upon or influenced by the opera-

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tions of the gas troops. In normal operations telephones, runners or dispatch riders may be utilized. Use of telephones is not advisable since unusual activity is apt to arouse suspicion. Dispatch riders are not reliable. A good runner system is therefore essential. In planning operations, runners must be provided for, and trained. They are always sent in pairs, and should be sent frequently over their routes, both by day and night, to insure proper liaison in action.

From company headquarters to the rear the army dispatch service should normally be used. All messages should be properly addressed and marked "to be called for." Messages for Regimental Headquarters of Gas Troops will normally be sent "in care of Army Message Center," for Battalion Headquarters "in care of Corps Message Center."

In active operations where platoons may be detached from company headquarters, it may be inadvisable to utilize company runners, in which case messages may be sent to company "in care of Division Message Center."

Since both Stokes mortars and Livens projectors are more or less crude forms of artillery, they have large dispersions of shots, both in range and deflection. Moreover, due to defective propellants, etc., shorts quite frequently occur. These short shots may fall only one or two hundred yards from the emplacement and if the fuse is armed they explode and become a source of danger to our own troops. It therefore becomes necessary in conducting Stokes and Livens projector operations to prescribe certain safety zones for our own personnel and to remove all troops from territory outside the safety limits.

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CHAPTER XI

Tactical Use of Gas, Thermit and Smoke by Gas Troops, Choice of Weapons, Training of Gas Troops, Liaison, Service of Security and Information, Training of Special Detachments.

The amount and the kind of gas used by gas troops should conform to tactical conditions, having due regard for wind and terrain conditions.

In an Active Offensive.—Gas may be correctly used as follows: (a) Preceding an attack, all enemy targets should be kept under a gas atmosphere, allowing only a reasonable time for clearance before the arrival of our troops. Only by so doing can the full benefit be derived in producing casualties, demoralization, reduction in fighting efficiency, and morale. (b) During a temporary check of an advance, extending from a few hours to several days, gas should be used on enemy concentrations, villages, strong points, woods, reverse slopes and machine-gun nests. (c) During organization and consolidation of the line gas should be used as for a temporary check, with special attention to sectors from which counterattacks may be launched. (d) During nights of an advance gas should be used on enemy supports and reserves, and on machine-gun nests and strong points. (e) Against machine-guns just before an attack, a judicious use of gas by Stokes mortars is an effective means of handling

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this form of defense. Placing from two to ten bombs of phosgene, depending on wind and terrain conditions, in a machine-gun nest establishes a local concentration sufficient to kill and force enemy to wear masks or abandon guns. The gas will have dissipated sufficiently by the time of arrival of our own troops to be safe. Close coöperation between the advanced infantry units and gas troops will allow this result. Troops must become accustomed to the smell of slight concentrations of phosgene, and should be taught to advance through or around it, just as they are trained to follow a barrage.

In Stabilized Warfare.—Surprise shoots of high concentration may be used on enemy concentrations, machine-gun and minenwerfer emplacements, strong points, trench intersections, and from one end of the line to the other, when conditions are favorable.

Thermit may be used under conditions similar to the above, when conditions of wind or terrain prevent the use of gas.

The intelligent use of smoke in modern infantry tactics offers many advantages arising from concealment and deception. It may be correctly used by gas troops as follows: (a) To mask enemy observation posts and blind hostile machine-guns. (b) To cover front and flanks of attacking troops. In frontal screens care must be exercised to place the smoke screen, preferably on the enemy trench system, so that an enemy barrage laid on the screen will not catch our own advancing troops. (c) As a feint to draw the enemy's attention to a front which it is not expected to attack, causing him needlessly to retain troops and expend ammunition. (d) De-

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ceptive screens to simulate general or local attacks. Gas should generally be used with smoke in these cases. A proper use of gas in connection with smoke screen work will cause the enemy to expect gas whenever smoke is used. This offers a tremendous advantage to our own troops. (e) To conceal concentrations of our guns and troops, and to screen roads and movements. (f) To cover construction of bridges and trenches in the face of the enemy.

The use of smoke should be such as to lead the enemy to expect or anticipate some object other than the real one.

The Stokes Mortar.—The mortar gas bomb is adapted to any of the cases set forth above. The mortar is especially useful in an active offensive where its mobility permits it to be pushed far forward and brought into operation on short notice. With efficient transport, gun teams can readily follow the reserve battalions of attacking regiments and be brought into action when required on enemy machine-gun nests or concentrations within two hours. This weapon is particularly adapted to the formation of local high concentrations, and is one of the best means of silencing hostile machine guns or minenwerfers within range. The smoke bomb is used effectively under all conditions given above. The mortar thermit bomb is used primarily for its demoralizing effect, against enemy machine-guns, of concentrations within range It is not as effective as gas, but can be used irrespective of wind directions. It may at times be used where conditions are unfavorable for smoke, or in addition to smoke, on

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strong points, trench intersections, and machine-guns. It has a considerable terrorizing effect.

The Projector.—The projector gas drum, with its thirty pounds of gas, is an excellent weapon for producing high concentrations in surprise shoots. It is especially effective against enemy concentrations, in villages and woods.

Due to its longer range, it can be used when Stokes mortars cannot. On the other hand, the weight and bulk of the equipment hinder its use on a rapidly moving front. With a length of carry not to exceed 500 meters from the limit of mortar traffic to the emplacements, from 100 to 150 projectors can be installed and discharged in one night by one company. This makes the projectors an efficient weapon during temporary checks, or during organizations and consolidation of the line.

Projector drums filled with high explosive may be used whenever wind conditions prevent the use of gas. They contain large charges in a case which is much lighter than an artillery shell, and are very deadly against troops in the open. They may also be used to demolish wire.

Cylinders.—A cylinder gas attack against suitable targets is undoubtedly the most effective means of using gas. High concentrations may be established over wide areas, and to depths of 10 or 15 kilometers. Even when the enemy has been aware that an attack was probable, there have been casualties amounting to nearly 10% of the enemy forces in the area affected. In addition, the gases, being highly corrosive in high concentrations, attack the metal parts of all guns and rifles. A cylinder at-

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tack, with a suitable wind, may be made immediately preceding an attack along the entire front. It can be closely followed by the infantry and will succeed in thoroughly breaking the defense.

Training of Gas Troops.—In the training of gas troops it must be kept constantly in mind that they are strictly fighting troops who will be required to carry on their operations in the foremost areas. They must be trained to insure correct technical execution with their special equipment, as well as to know how to handle themselves in action as Infantry, and take care of themselves in all emergencies of front line work.

The course as outlined herein is of the most intensive character, but must be considered of an emergency nature made necessary in order to place troops in action at the earliest practicable moment.

In addition, the assumption is made that the troops are organized and equipped, have a full complement of officers and at least half of their noncommissioned officers, and that they have received preliminary instructions, including the simpler close order movements up to and including the Battalion Parade.

The course is divided into two phases, the first consisting of eight weeks and the second four weeks. The first phase consists of the school proper and is divided roughly as follows: (a) Four weeks or forty-four drill periods devoted to special training in the use and operation of the special equipment. (b) Two weeks or twenty-two periods to infantry training. (c) Two weeks or twenty-two periods devoted to target practice, instruction and firing.

The second phase covers four weeks, during

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which platoons or sections are attached to units of experienced troops actually operating at the front. During this phase troops under instruction will assist the experienced troops by providing additional labor and gradually working into the operations, fixing the work of the first phase definitely in all details, under the conditions met with in actual operations at the front. Where it is impossible to do this, an additional four weeks should be allowed and the entire phase used in improving discipline, technical execution, and the carrying out of operations under all simulated conditions, of front line work.

Underlying all instruction must be a keen fighting spirit. Both officers and men must be made to appreciate from the very start that the ultimate and sole object of the work of this organization is to produce enemy casualties and assist other organizations to produce enemy casualties. Its success and value to the Army and country can be measured directly in enemy casualties. Gas troops are carefully instructed in their part in the team work necessary to the success of tactical operations in which they may be engaged, especially in the necessity of giving loyal and faithful service to the commanding officer of the infantry unit under whose orders they may be directed to operate.

Officers and men must appreciate that absolute discipline, and compliance with orders and instructions, are not only essential to greater direct success, but also afford the only real means of protection against large casualties in our own personnel. The men must not be allowed to drill in an indifferent or aimless manner. The picture of ac-

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tual combat must be kept in the mind of the instructor and transmitted to those undergoing instruction.

Lectures are reduced to a minimum, made brief and whenever possible given in connection with explanations and demonstration of equipment in the field. Gas defense training is continued during the entire course of training, using any available time and under conditions which will leave every man capable of protecting himself in extreme emergency.

School Phase.—It is essential that the officers who are to actually lead the troops be trained with them, and know their men. This necessitates dividing the personnel into six classes, dividing along tactical lines of the units where possible. These classes are as follows:

Class A—One-half of commissioned personnel.

Class B—One-half of commissioned personnel.

Class C—One-half of non-commissioned personnel.

Class D—One-half of non-commissioned personnel.

Class E—One-half of remainder of units.

Class F—One-half of remainder of units.

Classes A, B, C and D are given sufficient actual field training with the special equipment to insure not only a thorough understanding, but also correct mechanical execution. Officers are trained separately from the other ranks, and are required to actually handle and carry loads, use the pick and shovel, and do all the practical work. They also carry out operations, including transportation of material, both before and after the operation.

Throughout the course of instruction the strictest

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attention is paid to discipline, the routine administration of the units, and in as far as possible, the routine functioning of officers and men. Strict attention is paid to the performance of guard duty. Messing arrangements are carefully supervised and additional training given in the handling of rations. Billeting of the men is given careful consideration. Sanitation and proper policing is carefully watched. Bathing of the men is done by schedule and supervised.

In the general training stress must be laid on the absolute necessity of learning routine administration, the proper handling and care of men under the better conditions of the rear areas, or training camps, so thoroughly that both officers and men will be able to take care of themselves under the adverse conditions of the front line work. Discipline and insistence on the performance of every detail of this work is essential.

Infantry Training.—This includes (1) Physical Training. (2) School of the Squad. (3) School of the Platoon. In the work of the gas troops the platoon is the working unit and it should be an entirety in itself. It should be trained as a unit and should work together. It should be so organized that it can undertake independent operations. (4) School of the Company and the Battalion. Ceremonies should be given a prominent place in the schedule. As the training progresses and the units are split up undergoing technical training, the parade and review offer the best means of keeping the men set up and snappy. (5) Guard Duty. Formal guard mounts should be held. Especial care must be taken in the instruction of sentinels; they must

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be made to realize the serious nature of their charge when posted as sentinels, in time of war. Any laxity in the training area may result in the gravest offense in the forward area. (6) Extended Order. In the close order work correct execution should be the keynote. This should be obtained at once, and the extended order taken up at the earliest opportunity, maintaining just sufficient close order work to keep the men set up and in hand. Extended order instruction should progress as rapidly as is consistent with correct execution to field maneuvers with especial reference to service of security, patrolling, inter-communication and thorough control. (7) Full Marching Order. In forward areas the men will be required to make many marches under full pack, frequently bivouacking in the open. They will be trained how to carry the essentials, and only the essentials, as well as how to go into bivouac and take care of themselves. Only by doing this frequently, and under the closest supervision, will it be possible to carry on efficiently forward where every ounce of energy of both officers and men must be conserved. (8) Fighting Order. Men should be required in all field operations to go equipped as they would actually go into action, with the exception of rifle ammunition, which should be used during the last week of their training, but after they have had range practice. (9) Gas Defense Training. In the first drill periods careful instruction must be given in the correct mechanical adjustment of the respirators. This instruction must be followed up during the entire period of training by frequent drills so as to insure prompt and correct adjustment under all conditions. This is of special

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importance in night work, and night marches should be made with the respirators adjusted. Men should be trained to fire Stokes mortars with respirators adjusted. Instructors should pay special attention to requiring men to adjust the mask at odd times when engaged on other work, such as digging in projectors, carrying material forward, and the like.

The use of a mild lachrymator will materially assist in showing the importance of this work and assist in checking up delinquencies.

Liaison.—It is very important to select smart, intelligent men as runners. They should be men who are above the average in soldierly qualities, but not mature enough for non-commissioned rank. They should receive the same trainnig as other enlisted men, but when they have learned the technical work and drill, they should be given special instructions in map reading, use of the compass, finding their direction at night, and carrying verbal messages from Battalion or Company Commanders to Company Officers without any alteration.

During practice operations on the training ground they should be used by the officers in conveying code messages relating to the operation and they should be practiced at night, getting across country after dark.

Each officer selects and trains two runners for his own use. He is responsible that these men are fit for the job, and that they realize the importance of the duties in hand.

When companies move up to battle positions, these men are required to accompany officers on reconnaissances of the advanced line, to act as guides for carrying parties, as runners attached to

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an assaulting battalion, or left as runners to wait important messages at a Divisional, Brigade, Regimental or Battalion Headquarters. When on the last mentioned duty, they must not leave the message center or headquarters day or night until relieved.

They must have a good sense of direction and be able to find their way over desolate country at night with few visible landmarks.

When moving about in the advance zone an officer is accompanied by at least one runner, so that the latter will have a thorough knowledge of the country and be in a position to convey messages from his officer at any later time to the company headquarters, or to any infantry headquarters. This is especially necessary during an operation where the officer is busily engaged in his work of preparation, and has to send back reports of progress of same.

Service of Security and Information.—This should follow the principles laid down in the Field Service Regulations with special attention to the following:

Secrecy.—The success of these operations depends largely upon the attack being a complete surprise to the enemy. Codes must be used. Care should be exercised in the use of telephones. Telephones should not be used for conversation in "clear" or at regular intervals, as in the transmission of meteorological data. When operating with other units in the line greatest care must be exercised so as not to indicate increased activity. The regulations in force in the particular sector must be strictly complied with.

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Camouflage.—The simpler principles should be covered which will allow an officer to decide as to color and texture of material, quantity and dimensions of artificial material, as well as to make the best out of natural concealment in woods and accidents of the terrain. Track discipline is of especial importance. The position should never be left either before or after firing before it is thoroughly camouflaged. Frequent aerial photographs should be obtained as work progresses on the larger operations.

Meteorology.—There are certain fundamental principles in meteorology which every officer should understand. All gas operations are dependant in more or less degree upon wind and weather conditions, but with an understanding of the simpler principles and complete data, not only from the Meteorological Service itself, but from that obtained by the Meteorological Sections of the units themselves, it is possible to predict and make a much larger use of gas than would otherwise be possible. This is so important and will be of such greater importance in future operations that this knowledge must be obtained. The safety limits must be thoroughly understood.

Service of Supply.—Under this should be covered all the details of supply, whether automatic or otherwise, and a definite understanding had as to the procedure in each case.

Map Reading and Making.—It is not only disgraceful but criminal for an officer to take his men into action over unfamiliar ground without the ability to keep himself properly located at all times.

Organization of an Attack.—Operations such

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as the gas troops must carry out frequently necessitate the movement of large amounts of material and use of a considerable number of men. As in any other operation it requires careful planning and organization. Time is an essential element and must always be taken into consideration. If normal contingencies are allowed for, the adverse conditions of front line work will usually add sufficient difficulties to tax the energy and ability of all concerned without allowing for mistakes and lack of supplies.

Writing of Orders.—All officers must be trained to write clear, complete and correct orders covering units which they will be expected to lead. After a thorough explanation of the necessity and the details to be covered in an order, practical instruction in connection with actual operations undertaken in the general training will usually suffice if these orders are carefully checked and mistakes corrected.

Meteorological Section.—Eight men in each battalion should be thoroughly trained to take and properly record meteorological data. They should know how to interpret data received from the Meteorological Service and apply it to local conditions. A regular system should be instituted in each battalion and company so as to keep all officers thoroughly informed as to wind and weather conditions.

Runner Service.—Each battalion and company should have four trained runners and each platoon leader two trained runners. These men should be carefully selected, intelligent and resourceful. They must be instructed in the operations of the units and their relation to the other troops with which

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the unit is operating. They should be trained to carry messages correctly under the most adverse conditions, and must be made to realize that upon their work the failure or success of an operation may depend.

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CHAPTER XII

Use of Gas by the Air Service, Tactical Use of Incendiary and Smoke Bombs, Altitude Flying and Oxygen Apparatus, Chanard Incendiary Bombs, Training Smoke Bombs.

When the United States entered the European war no satisfactory incendiary bombs had been produced by any country, and consequently a long period had to be given over to experimentation before quantity production could be attained. In due time two types of incendiary bombs were produced, the first being of the scatter type, designed for use against light structures, grain fields, and the like, and the second of the intensive type for use against large structures and well defined targets. The American intensive bombs weighed about 40 pounds each and contained charges of oil emulsion, thermit, and metallic sodium, a combination of chemicals that burns with intense heat. These bombs were used against ammunition depots or any structures of an inflammable nature. The sodium in the charge was designed to have a discouraging effect upon any one who attempted to put out the fire of the burning charge, since metallic sodium explodes with great violence if water is poured upon it.

One of the interesting phases of the bomb manufacturing program grew out of the necessity for target practice for aviators. For this work *dummy*

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bombs of terra cotta were built, costing about a dollar apiece. Instead of loading these bombs with explosive, there was placed in each a small charge of phosphorus and a loaded paper shotgun shell, so that the bomb would eject a puff of smoke when it hit its object. The aviators could see the smoke puffs and thereby determine the accuracy of their aim.

Night-flying is one of the most hazardous duties of the aviator, the chief danger being in landing. The aviator at night can usually see the ground faintly, but he is unable to make an accurate judgment of the distance of his machine above the ground. This danger is greatly alleviated when *wing-tip flares* are used. The wing-tip flare consists of a small cylinder of magnesium material in a metallic holder, one flare being fitted under each lower wing of the plane and being controlled by a push button in the pilot's cockpit. Pressure on the button sends an electric spark into the magnesium and touches it off. When ignited the flare burns for about 50 seconds with the brilliant light of 20,000 candle power, the reflection from the under surface of the wing lighting up the field for an adequate distance in all directions.

To enable the night bomber to see his target a piece of pyrotechnics known as the *airplane flare* is employed. This is a great charge of magnesium light held in a cylindrical sheet-iron case nearly 4 feet long and 5 inches in diameter, and weighing 32 pounds. Within the cylinder is not only the magnesium stick but also a silk parachute, 20 feet in diameter. The entire cartridge is attached to the airplane by a release mechanism similar to those

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holding the drop-bombs. When over his objective at night the pilot or observer touches a button and the entire cartridge, iron case and all, drops from the plane. A pin wheel on the lower end of the case is instantly spun by the rush of air, and the resulting power not only ignites the magnesium but at the same time detonates a charge of black powder sufficient in force to eject from the case the flare and its tightly rolled parachute. The parachute immediately opens; and the burning flare descends slowly, flooding a large area of the ground below with a light of 320,000 candle power, this light burning for about ten minutes. Such a light not only enables the bomber to drop his destructive missiles accurately, but dazzles the eyes of anti-aircraft gunners below and makes their aim inaccurate. The light of this flare is so strong that it is possible for the airplane above to obtain photographs of good detail on the darkest of nights.

The first oxygen apparatus for high altitude flying was designed for the British Air Service, and the first squadron which used the apparatus reported that its men gave six times the service of any other British squadron. The American Air Service adopted the Dreyer oxygen apparatus, which was the original device produced by the British. The first British apparatus was heavy and built to supply oxygen to one man only. It was afterwards reduced in weight, changed to take care of two men and re-designed to meet American factory methods. In its present state of development this equipment consists of a small tank or tanks, the pressure apparatus, the tube leading from the reservoir, and the face mask covering the mouth

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and nose. The mask has combined with it either the interphone, a mechanism which cuts off the roar of the engine from the ears of the passengers and allows the pilot and observer to talk freely with each other, or in certain cases the receiver of the radio telephone or telegraph. All military planes (day and night bombing, pursuit, chassé, and Army and Corps observation planes) flying above an altitude of 10,000 feet are required to be equipped with oxygen apparatus.

French Chanard Incendiary Bomb.—This bomb, of the intensive type, is commonly employed by the American Air Service, and consists of a case or body, nose, stabilizer wings, H tube, quick match, tubes, vents, firing mechanism and safety propeller.

Construction.—The bomb body or case is composed of two longitudinal halves of an ellipsoid of revolution. The edges of these are soldered to the annular core or H tube. Both the body and the H tube are made of tin plate. The H tube is filled with special thermit mixture, which is known as C. D. powder or Daisite No. 2. The charge is 275 grams. The main body is filled with Chanard incendiary material. This material consists of a plastic semi-fluid mass which on combustion flows freely. It consists principally of nitrocellulose and resin with a mixture of turpentines.

Firing Mechanism.—This consists of a safety propeller with screw and plug into which screws a socket, striker, striker spring, three steel balls, striker sleeve, and quick match or fuse in the tube.

Method of Operation.—During shipment the propeller is held stationary by two strands of wire attached respectively to the propeller and the body

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of the bomb. The firing mechanism is permanently locked by means of a propeller screw which absolutely prevents accidental functioning. Before the bomb is placed in the suspension on the plane, the wires which hold the propeller are removed and the propeller unscrewed by no more than four complete turns. The bomb is then placed in the suspension where the propeller is prevented from revolving by means of a spring wire which engages the blades. The firing mechanism consists principally of a striker driven forward by a spring. The tail of the striker, which is hollow, is held in place by three equi-distant balls separated by the thickness of the striker. These balls are held in place between the vertical wall and the striker sleeve and the propeller stem. As the propeller unscrews, the stem moves with almost no frictional resistance, until the lower end passes the equator of the three balls. At that moment the striker spring comes into play. The balls drop into the striker and the striker is driven with considerable force against the detonator.

Action.—As the bomb is released from the airplane, the current of air produced by the falling body, unscrews the propeller. Five seconds later, that is to say, at a distance of from 60 to 80 meters from the machine, the firing mechanism is automatically unlocked and immediately the 8-second fuse or quick match contained therein is ignited. When that time has elapsed and the bomb has descended some 500 meters or more, the firing mechanism is blown off by a slight explosion and the material in the H tube is ignited at four different points. The bomb is split in two halves by melting

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the solder and the main incendiary mass is ignited. As this action takes place, the bomb is still dropping through the air, and it reaches its target in flames. The blazing contents are deposited on the target without the necessity of an explosion. Here it continues to burn for some 18 minutes. A black smoke is given off which hinders fire fighting.

Marking.—The bomb is painted with light red oil paint. Around the vent holes are painted white circles and on the body of the bomb are the markings "C. D. 120."

When these bombs are removed from the case, they should be lifted by their suspension keys. If replaced, they should be deplaced in a horizontal position with the suspension keys crossed.

The Chanard Incendiary Bomb is so designed that it will penetrate an ordinary roof and deposit its contents in the interior of the building. The incendiary material of the bomb being already ignited when it hits the target, it continues to melt, run and burn as it runs communicating this fire to any inflammable material which it reaches. A bomb of this type should, of course, be used only against well defined targets where a direct hit is possible, for if it should miss the target and strike on the ground or other uninflammable material its effect would be nil.

Incendiary Bombs of the Scatter Type possess the advantage of not requiring a direct hit, because the material scatters to a certain extent; but they possess a disadvantage in that the amount of incendiary material in any one place is small and unless the material is quite inflammable it will not be set on fire.

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French Training No. 2 Smoke Bomb, Steel.—This bomb consists of a firing pin, shear wire, safety pin, cartridge plug, gaine head, steel ogive, 10 caliber cartridge, filled with "T" powder, sheet steel body, gaine tube, ballast of cast sulphur, stabilizer wings, tin tube containing titanium tetrachloride, cork plug, cement plug, and cotton wad. All the metal parts are made of steel or iron. "T" powder is a highly nitrated sporting powder containing less than 1.3% moisture.

Method of Operation.—The bomb is designed so that it has the same trajectory as regular bombs and is used to train aviators in bomb dropping. When suspended in the dropping mechanisms the safety pin is removed. On striking the objective the shear wire is cut and the firing pin impinges on the detonator of the cartridge, which is thereby fired. This expels the tin tube containing the fumigen and at the same time breaks it, causing a scattering of the liquid titanium tetrachloride, which substance produces a white cloud of smoke visible from the airplane.

Marking.—The bomb is painted black, but has no special markings other than the Inspector of the Forges.

French Training Smoke Bomb, Cement.—This bomb is a modification of the foregoing steel smoke bomb. It has narrower stabilizer wings and a more streamlike shape. A different gaine head is used and the gaine reinforcing tube is done away with. The main difference between this bomb and the French Training No. 2 smoke bomb, steel, is that the body is made of cement rather than of steel filled with cast sulphur, and that the gaine

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tube has a reinforcing tube near the nose end in the older model.

Method of Operation and Marking.—The method of operation and marking is the same as for the French Training No. 2 smoke bomb, steel, except that the stabilizer wings only are painted black, the body being unpainted.

These bombs are designed for use only in training bomb droppers in the use of bomb sights and release mechanism. On impinging on the ground the bomb expels its charge of fumigenite (titanium tetrachloride) which gives a smoke cloud which is visible to the bomb dropper in the plane, thus informing him as to whether or not he has hit the desired target.

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CHAPTER XIII

Gas Zones, Gas Alarms, Gas Sentries, Action during and after Gas Attack, Division Organization of Disinfecting Service, Duties of Regimental and Battalion Gas Officers.

Two zones, known as the "Alert" and "Danger" zones, are defined in the area of the armies. The approximate extent of these zones is as follows:

Alert Zone.—The area within three kilometers of the front line, together with areas especially subject to shelling with gas, including all active battery positions and other points, such as villages, cross roads and convenient concentration points for troops, to be designated by the Division Gas Officer.

Danger Zone.—The area between three and ten kilometers to the rear of the front line.

Within the alert zone all persons in or connected with the military service wear the respirator in the "Alert" position. Every man is clean-shaven, except that a mustache may be worn, and the hair is kept short in accordance with Army Regulations. Sleeping men must not remove the respirators from their bodies. A sufficient number of sentries must be posted to awaken all men quickly in case of a gas attack. *Respirators and all gas defense appliances will be inspected daily in this zone.* Horse respirators are worn in the "Alert" position.

Within the danger zone, troops carry their re-

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spirators at all times, except when asleep, in which case the respirators are within immediate reach. Respirators and gas defense appliances are inspected three times a week. Horse respirators are worn in the "carry" position over all equipment.

Sentinels and military police are instructed to allow no person connected with the Military Service to pass without complying with all the rules relating to the wearing of respirators. They report all cases of infringement of the above orders, and copies of these reports are furnished to the regimental or divisional gas officers.

The above-named zones are conspicuously marked by each regiment in such a manner as to attract the attention of persons entering them. When not carried in the "Alert" position, the box respirator is carried in the slung position, this is, over the left hip, the sling passing over the right shoulder. Nothing is worn so as to interfere with the immediate shifting of the respirator to the "Alert" position.

An efficient system of gas alarms is provided throughout the "Danger" zone, and especially in the "Alert" zone. This includes Klaxon horns, rattles and triangles, together with other signals approved for this purpose by the Division Commander on recommendation of the Division Gas Officer. These alarms are used solely for the purpose of giving warning in case of a gas attack. When necessary, civil authorities within divisional areas are warned by Division Headquarters. Any person becoming aware of the presence of gas or of an impending gas attack gives alarm by means of the alarm signals or by calling "Gas." Any one who

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knowingly gives a false gas alarm is tried by court-martial.

All sentries act as gas sentries, and if necessary, special gas sentries are posted in order that the alarm may be promptly and properly given. Special gas sentries have definite areas to alarm in the event of a gas attack. Two sentinels are posted at night. When deemed necessary one of them wears the respirator completely adjusted. They relieve each other of wearing the respirator every half hour. All working parties of ten or more men have a gas sentry posted. All sentries, traffic control men, military police, etc., when on duty act as gas sentries, and are provided with suitable alarm devices when necessary. Sentries are posted over all men sleeping and all men in dugouts or shelters, and each sentry is definitely responsible for the group assigned to him. The loss of a few seconds in giving gas alarms may increase very greatly the number of casualties. In case of gas attack, sentries shout "Gas!", put on their respirators and then give the alarm. If possible, sentries should be placed in positions overlooking the enemy lines to detect the characteristic flash which accompanies a projector attack. Sentries should be carefully instructed in methods of detecting the various forms of gas attacks, such as the hissing sound accompanying cloud attacks, and the flash, loud explosion and whirring of projectiles in a projector attack. In case of doubt, especially when a projector attack is suspected, alarm is given. As frequent false gas alarms will eventually cause troops to disregard an alarm, gas sentries are carefully selected and thor-

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oughly instructed, so that false alarms are reduced to a minimum.

Any concentration of troops within 1500 yards of the enemy lines should be avoided, unless the tactical situation so requires. Within this area every precaution must be taken to avoid giving information to the enemy of localities in which troops are concentrated, since such points of concentration are chosen as targets for projectors.

At the instant that any gas alarm is given, all ranks immediately put on respirators and wear them until the order to remove masks is given by an officer acting upon the advice of a Gas Officer. In the case of isolated groups and in the absence of a Gas Officer, the order to remove masks is given by the non-commissioned officer in charge, who will report this action promptly to the nearest officer. In case the gas attack is followed by an assault of enemy infantry *not* wearing masks, respirators may be removed without formal order. Any officer or man who fails to put on his respirator when warned by a Gas Officer or by a general gas alarm of the presence of gas, or who removes his respirator without proper authority, is disciplined. If a person under such circumstances becomes a casualty, he is considered as wounded "not in the line of duty."

The blanket curtains of protected dugouts and cellars are properly adjusted, *fires* in such dugouts *put out and flues closed*. The organization attacked at once notifies battalion headquarters and troops on the flank of the attack. Battalion headquarters in turn notifies regimental headquarters and the

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Regimental Gas Officer. Regimental headquarters notifies divisional headquarters of all gas attacks. Additional spreading of the alarm takes place when necessary. No one enters a gassed area into which he is not obliged to go in line of duty, and all who are within a gassed area refrain from all movement and conversation not required by military necessity.

When the tactical situation permits, troops not on duty should be allowed to remain in gasproof dugouts, *and to remove their masks, if the dugout is entirely free from gas.* An additional sentry must then be posted inside the dugout at each entrance until the area is free from gas. *All unnecessary movement and talking must cease.* In case of a cloud gas attack, all bodies of troops or transport on the move will halt, and working parties cease work until the gas cloud has passed. If a relief is in progress, units should stand steady as far as possible until the gas cloud has passed. Supports and parties bringing up ammunition and grenades are only moved up if the tactical situation demands. As soon as possible after or during a gas attack, gas officers determine whether a "persistent" or a "non-persistent" gas is being employed. When the situation permits a position extensively bombarded by the most persistent gas, namely, mustard, must be temporarily evacuated.

If mustard gas is used, the area is dangerous, for one or two days, and sometimes longer, *unless the tactical situation forbids,* and an area subjected to such a gas attack should be promptly evacuated for a period of three days, or until pronounced safe by the Divisional or Regimental Gas Officer. If prac-

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ticable, the Division Gas Officer will be consulted. The evacuation should be made upward from the shelled area when possible. For this reason alternative positions should be selected in advance, and all the necessary preparatory steps should be taken to accomplish a rapid and orderly change to such positions in case of necessity.

In case a position shelled with mustard gas must continue to be occupied, respirators are worn continuously, men must not be permitted to sit or lie upon contaminated ground, and other precautions must be taken to avoid contamination of the body or clothing. In such a case, frequent reliefs should be established. After a gas attack, gas officers take immediate steps to clear and disinfect gassed positions. They report when the position is safe. As long as the slightest odor of mustard gas is detectable, the position must be considered dangerous. It is especially to be noted that the odor of mustard gas in slight concentrations is not unpleasant, and that the gas produces no irritation for several hours. During a mustard gas attack, precautions must be taken to avoid contamination of dugouts from the clothing and especially from the shoes of men who enter. Men who have been even slightly gassed are treated as casualties, and withdrawn promptly from the gassed area with the least possible exertion on the part of the man gassed. Especially in the case of a mustard gas attack, it is important that fresh clothing be available and that the clothing should be changed and the man given a bath with soap and water as soon as practicable.

After a gas attack, food supplies which have been exposed should be thoroughly inspected, and any

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food suspected of contamination with gas should be condemned. Many casualties have been caused by the use of water from shell holes. Regardless of whether recent gas attacks have occurred, all water from shell holes must be regarded as contaminated, and must never be used for any purpose whatsoever.

It is customary for a gas attack to proceed in waves or salvos at variable intervals, *therefore, a sharp lookout is maintained for a repetition of a gas attack.* When the tactical situation permits, troops which have been subjected to gas attacks are withdrawn. Commanders of units relieving one another are responsible that all the anti-gas stores are handed over and receipted for by the respective gas officers of the units.

In order to provide the most efficient means for the purification of ground which has been shelled with "mustard gas" special disinfection squads are designated and trained by each Regimental or Battalion Gas Officer for this purpose. These squads are organized in the various units according to the tactical employment of these units; each squad to be under the immediate directon of the gas non-commissioned officer of that unit. Except in case of "mustard gas" shelling, the men composing this squad are free to perform their regular duties. This does not apply to the gas non-commissioned officers, who are assigned no duties which might interfere with their duties as gas non-commissioned officers. These men, however, spend such time as may be necessary in order to make them proficient in their work, according to the discretion of the Regimental Gas Officer. The duties of these disinfecting squads

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are to disinfect "mustard gas" shell holes with chloride of lime and to cover this chloride of lime with earth; to bury leaking gas "duds;" to mark the location of sound gas "duds," which location is given the Regimental Gas Officer; and to carry out infected equipment and clothing from "mustard gas" infected barracks or dugouts, when an evacuation has been ordered.

Field hospital, ambulance and signal companies, and other units attached to the Division are looked after by the disinfecting party in whose area they are operating. The equipment for each man in the disinfecting squad, in addition to the small box respirator, consists of a suit of special oiled clothing and two pairs of oiled gloves. Immediate disinfection is necessary to prevent mustard gas casualties, and every effort should be made to expedite the arrival of a disinfecting squad at a shelled area.

The following is a typical memorandum of the duties of regimental and battalion Gas Officers: 1. Report all gas shelling promptly, giving time, location, weather, wind, and number, size and kind of shells used, and any casualties reported. 2. Report immediately any mustard gas shelling in your area. 3. Report promptly all changes in gas personnel. 4. Report name, rank, and organization of all officers violating standing orders of gas defense. 5. Insist on daily inspections of respirators in "Alert" zone and twice weekly in "Danger" zone. Check up these inspections personally to be positive they are being carried out. 6. Make sure by frequent inspections and tests that alarms are adequate and in working order. 7. Frequent instruction of all sen-

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tries is mandatory. They must be thoroughly familiarized with all their duties. They must know all standing orders of Gas Defense. They must know how to detect a gas attack, how and when to give the alarm and when to awaken sleeping men over whom they may be posted. 8. Make sure that no men are permitted to sleep without being near a sentry who knows where they are. 9. Question and instruct all gas non-commissioned officers frequently, reporting those (by name, rank, and organization) considered incapable, those who neglect their work, and those who have too many other duties to perform. 10. Make sure that when a man loses his respirator or when he turns one in for replacement that has been *rendered unserviceable through carelessness or by intention*, the new one issued is charged against his pay account, and see that further disciplinary action is taken. 11. Make sure that all units in each area are well known. 12. Submit brief report each week covering work done during the week as Gas Officer, and, in addition, nature of other duties performed and the amount of time required for same.

Company gas non-commissioned officers assist officers at the inspection of respirators, taking particular care to see that each man's satchel is marked with his own name, and in making such local repairs as are possible. They assist in training men in the use of gas defense appliances and, under the Company Commander, they have charge of all gas defense trench stores, alarm devices, gasproof shelters and stores of fuel for clearing shelters. On relief they assist the Company Commander in taking over all gas defense trench stores (by daylight, if pos-

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sible). They make wind observations as directed by the Division Commander on recommendation of the Division Gas Officer, and report any change of wind to the Company Commander. After a gas shell bombardment, if the use of a new gas is suspected, the gas non-commissioned officer takes samples of earth contaminated with the suspected gas. Such samples are handed to the Division Gas Officer through the Company Commander with notes as to the positions from which the samples were taken.

During and after a gas attack the gas non-commissioned officer should note down in writing as much information as possible on the following points: (1) Strength and direction of wind and general weather conditions. (2) Times at which the gas wave or gas shell bombardment started and finished. (3) Exact position and nature of place affected by gas or gas shell. (4) To what extent telephone dugouts, covered gun and machine gun emplacements, etc., were affected. (5) The approximate number of gas shell used and their caliber. (6) The position of dud shell and fragments of shell, etc.

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CHAPTER XIV

Respirators, Adjustment and Practice Drills, American Tissot Respirator, Fitting and Care of Canisters, Anti-Dimming Outfit, Respirators for Horses.

When training men in the use of respirators the following points are of importance: (a) Ordinary infantry drill should be combined with physical drill, including arm and leg exercises, leap-frog, and double-time. The time of practice need not exceed 15 minutes at first while wearing the respirator, but should be gradually extended. This drill should be in heavy marching order. (b) Practice in bombing, rapid loading and aiming, judging distance and rifle firing, should be carried out while the men are wearing respirators. (c) Officers and non-commissioned officers should receive the same training as the men and in addition, should be practiced in giving orders while wearing their respirators. (d) It must be realized that troops in the line always carry the respirator, and that practice in the rear should take this into account. Every effort must be made to approximate actual warfare conditions. Every opportunity should be taken to accustom men to carrying on their usual duties with the respirator adjusted. It is often necessary during and after a gas attack for men to wear their respirator for six or eight hours, or even longer when

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a highly persistent gas, such as mustard gas, is used. (e) Practice and drill in the use of gas defense appliances should be carried out as continuously as tactical conditions will permit. This applies especially to troops which return to the line after having been in rest areas and where the incorporation of drafts incompletely trained in gas defense measures make such training very essential.

American Tissot Respirator.—This respirator consists of a metal canister filled with a mixture of chemical granules and connected by a rubber tube to an impervious facepiece. Air is drawn in through the inlet valve which consists of a circular rubber disc fitted on a stud in the center of a perforated metal plate. Any poisonous gas is absorbed by the granules in the canister. The purified dry air passes into the facepiece, playing over the eyepieces, and keeping them clear. Air is expired through the outlet valve, the inlet valve closing in order to prevent air passing through the canister. If the inlet valve does not close properly, expired air passes into the canister, causing deterioration of the chemicals and discomfort to the wearer. The facepiece is held in position by a head harness of self centering construction which keeps it firmly against the face without discomfort. The complete respirator is carried in a satchel which is divided into two compartments, one of which holds the canister and the other the mask. The canister rests on a wire platform which raises it from the bottom of the compartment and allows the free access of air.

When respirators are issued they should be most carefully fitted. In some cases it will be necessary to change the length of the elastic by means of the

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buckles. When the fit of the mask appears satisfactory, it must be tested in tear gas and the test repeated at least every month. If possible, the test should be made in the gas chamber every time a battalion comes out of the line. Men should remain in the tear gas for five minutes, moving about and talking to make sure that the fit of the mask is good. When the fit has been tested, each man should write his name, but not his organization, on the lower part of the front of the satchel as worn in the "alert" position to insure that he does not exchange his respirator for another that may not fit him.

The most serious causes of damage to the respirators are: Water entering the canister and spoiling the chemicals, injury to the facepiece, and injury to the outlet valve. Respirators must be protected from wet as far as possible, and rough usage must be avoided. Nothing must be carried in the satched, except the respirator and anti-dimming outfit; small articles of kit readily cause damage to the mask. The inside of the facepiece should be wiped before it is put away, otherwise damage is caused by the rusting of metal parts, and by the rotting of the stitching.

To prevent freezing of the outlet valve during very severe frost, two or three drops of glycerine should be inserted through the slits at the bottom of the valve by means of a match or stick of wood. Supplies of glycerine are kept by Division Gas Officers for this purpose. Half a pint should be sufficient for 1,000 respirators. Inlet valves at bottom of canisters are not affected if kept dry. If

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moisture has entered and frozen, the valve must be removed, thawed, wiped dry and replaced. The inlet valve must not be treated with glycerine.

When canisters are issued, they are painted with the number of the month of issue. They are then replaced after the lapse of a certain number of months. They usually become ineffective through mechanical damage before they become useless chemically. The chemicals in the canister slowly lose their efficiency, even when nothing but pure air is breathed through them. This is due to the fact that the moisture in the air gradually cakes the granules, increases their resistance, and lowers their absorptive power. When the canister of the respirator is defective owing to wet, rust, or other damage, or has been breathed through for 40 hours in gas, and the respirator is otherwise in good order, the canister should be replaced by a new one.

In all operations great care must be taken to avoid damaging the rubber tube. Remove the tape on the wire. Turn up the twisted end of the wire at right angles to the tube. Press on the point of the "tool for detaching canister" under a single strand of wire near the twisted end. On pressing over the tool the wire will be cut by the sharp edge inside the V. Remove the wire. Insert both points of the V under the rubber, then, with the handle of the tool at right angels to the tube, move the tool around the neck to loosen the rubber from the metal. On continuing with an upward movement the tube will be detached. When fixing the new canister remove the plug of cotton waste from the neck of the new box, lick the neck and slip the rub-

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ber tubing over it so that the neck is completely covered, taking care that the facepiece is in the correct position relative to the canister.

The following drills are designed to teach officers and men to adjust their respirators accurately and quickly. The drill must be so thoroughly mastered that all will protect themselves instantly and almost automatically upon hearing the gas alarm.

Drill "A." To bring the Respirator to the "Alert" position.

1. **Sling Position.**—Respirator with sling over right shoulder. Satchel hanging on left side with press buttons closed and next to the body.

2. **Gas Alert Position.**—Being at "slung" position, (1) *Gas Alert.* Place the rifle between the knees. Slip the left arm back through the sling and bring the satchel around to the front of the body. Open the flap of the satchel. Take out the whip-cord with the right hand and pass it through the metal loop on the right hand side of the satchel. Raise the satchel to the chest with the left hand so that the slack of the sling falls over the back, pulling it down with the right hand and holding it there. Then take the sling in the left hand and with the right, pass the cord through the sling, then through the metal loop on the left side of the satchel and fasten it tightly with both hands after adjusting respirator to proper height on the chest. Fold flap over top to protect respirator from wet, but do not fasten.

3. **Alternative Position, Especially When Pack is Slung.**—Being at "slung" position. (1) *Gas Alert.* Place the rifle between the knees. Slip the left arm back through the sling and bring the

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satchel to the front of the body. With the right hand, grasp the metal hook at the left of the satchel and with the left hand reach behind the neck for the metal eyelet on the sling, pull down and fasten the two together. Open the flap and take out whipcord with right hand. Pass it through the metal loop on the right of the satchel, then around the back and secure it to the metal loop on the left of the satchel.

Drill "B." Drill "by numbers" to obtain complete and accurate adjustment of the respirator from the "Alert" position.

This drill will be alternated with one without the numbers to insure as quick an adjustment as possible, in which practice in holding the breath will be included. The drill must be practiced until complete and accurate adjustment is obtained by all ranks in six seconds.

The respirator in the "alert" position. The helmet is worn with the strap adjusted at the back of the head. One end of a lanyard is attached to the left loop of the helmet and the other is passed around the left shoulder.

Being at "alert" position with helmet adjusted: (1) *By the numbers.* (2) *Gas.* Stop breathing. Place the rifle, if unslung, between the knees. Insert the thumbs under flap and open satchel. Seize the facepiece with the right hand. *Two.* Bring the facepiece smartly out of the satchel to the height of the chin, holding it firmly in both hands with the fingers extended outside, the thumb inside at the binding midway between the two lower straps of the head harness. Stick out the chin. *Three.* Bring the facepiece forward, digging the chin into it. With the same motion, guide the straps of the harness

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over the head with the thumbs, knocking the helmet off backwards. *Four*. Grasp the outlet valve tightly between the fingers, to prevent the passage of air through it, and blow vigorously into the mask, completely emptying the lungs. *Five*. Feel around the edge to make sure the facepiece is well seated. Correct adjustment and head harness. *Six*. Replace helmet. Resume the attention.

Drill "C." To Adjust Respirator from Slung Position.

Being at slung position. (1) *Gas*. Stop breathing. Place the rifle, if unslung, between the knees. Pull the satchel around until it hangs in front of the body. Unfasten the flap and adjust the respirator as in practice "B," allowing the satchel to hang by the rubber tube. Replace helmet, and at once proceed to adjust the satchel in the "alert" position, as in practice "A."

Drill "D." Drill to teach method of testing for presence of gas.

Respirator being adjusted. (1) *Test for Gas*. Take a deep breath. With the right hand pull the facepiece slightly away from the right cheek, hold the breath, and sniff gently. If gas is smelled, readjust the facepiece, grip the outlet valve between the fingers and thumb, and breathe out hard.

Drill "E." To remove the facepiece.

Having tested and found no gas. (1) *Remove*. (2) *Facepiece*. Insert the first two fingers of the right hand under the facepiece of the chin, placing the thumb on the metal guard of the exit valve, bend the head forward, at the same time removing the facepiece with an upward motion of the right hand.

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Drill "F." Inspection.

The respirator being at slung position. (1) *Prepare for Inspection of Respirators.* Place the rifle between the knees. Slip the left arm back through the sling and bring the satchel around to the front of the body. Open the flap of the satchel. (2) *Inspection.* (3) *Respirators.* Examine the satchel and sling, make sure that metal hook and clasp and metal loops at each side are securely fastened. Remove canister and hold under left arm, the tube and facepiece hanging over the arm. Examine the interior of satchel to see that wire platform and anti-dimming are there, and that whipcord is in good condition and free from knots. *Two.* Examine inlet valve at bottom of canister. Examine the canister for rust spots and weak places by pressing lightly with the fingers beginning at bottom and working to the top. Watch carefully for holes in soldering at top of canister. See that the flexible tube is properly fastened to the canister, and to the metal elbow tube and is free from obvious defects. *Three.* See that the metal elbow tube is securely connected to facepiece and that outlet valve guard is not loose. Make sure that the outlet valve is in good condition, has no dirt or sand in it, has no tears, and is connected properly to elbow tube. *Four,* Examine the facepiece inside and out. See that chin rest is secure, that there are no pinholes or tears in fabric, that air passage to eyepieces is in proper condition and not torn away from fabric, that eyepieces are securely fastened in the facepiece. Examine the head harness and make sure that it is firmly attached to binding. *Five.* Adjust mask to face to test valves. Hold canister in left

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hand. Grasp outlet valve between fingers to prevent passage of air through it, and breathe gently in and out a few times. The inlet valve, if working properly, should vibrate back and forth. Test the outlet valve by putting a kink in the breathing tube to prevent the passage through it of air and attempt to draw air into the facepiece. If the outlet valve is in proper condition, it will not be possible to draw in any air. Remove respirators. *Six.* All men having defective respirators step forward one pace. All others replace the canister in the satchel, taking care not to twist the facepiece into wrong position, and return the respirators to slung position. Respirators should be inspected daily in the alert zone, and at least twice weekly in the danger zone. They must always be inspected before proceeding into the alert zone. It is the duty of all officers and non-commissioned officers and their assistants, to make sure that these inspections are carefully carried out. A respirator must always give complete and absolute protection. Its condition can only be determined by constant and careful inspection.

After all drills the eyepieces should be rubbed with anti-dimming, leaving a thin transparent film of the composition on the glass and the facepiece should be wiped dry, folded correctly and put away in such a manner that the rubber outlet valve is not bent.

The anti-dimming outfit is carried in the satchel, and contains a stick of composition and a piece of soft rag. Occasionally at inspection and always after each wearing of the respirator, the inner surfaces of the eyepieces should be cleaned and dried,

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a little of the composition rubbed on with the finger, and the surface rubbed with a soft rag until the film of composition is smooth and thin and nearly clear.

Horse Respirator.—In choosing locations for stables and horselines if within shell range, high, sloping, treeless ground is preferable as less likely to hold gas. Horses should not be allowed to stand on or be ridden over areas that have been heavily shelled by mustard gas, as the skin of the horse is more sensitive than that of man to the effects of this gas. They should not be allowed to eat grass that has been contaminated with mustard gas, or drink from infected shell holes. Horses exposed to mustard gas should be washed all over as soon as possible with soap and warm water, especially around the mouth, anus, and sexual organs. Horses must be practiced in wearing the respirator, as they will otherwise resist protection, and cause delay and annoyance in emergencies.

The horse respirator consists of a flannelette bag with a canvas mouthpiece which goes into the horse's mouth and saves the flannelette from being bitten through. The bag is provided with an elastic band which passes round the opening so as to draw the respirator close to the face when in use. The upper side of the mouth of the flannelette bag is furnished with a small unbleached calico patch by which the respirator is attached to the nose-band of the bridle or halter when in the "Alert" position, and while in use. Inside the bag and attached to the canvas mouthpiece there is a canvas frame which is stitched on to the bag in such a way as to prevent the material drawing into the nostrils when

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the respirator is in use. The whole is folded and carried in a canvas case provided with a flap, secured by three press buttons, and having two straps at the back by means of which the case is attached to the bridle or halter.

Horses can stand a higher concentration of gas than human beings without serious injury, and it is not, therefore, necessary to protect them against cloud gas attacks when they are a considerable distance back from the trenches. Nor is it usually necessary to protect their eyes. The respirator is primarily intended for use on transport animals when they are sent to the vicinity of the trenches with supplies and ammunition. In the case of gas shell attacks, horses should be protected wherever the shelling is heavy.

When not required for immediate use the respirator can be conveniently carried on the supporting strap of the breast harness, or if a zinc wither pad is worn, still more conveniently inside this pad. If a collar is used in place of the breast-strap, it can be carried in the channel of the collar where drivers often carry a sponge. However carried, the case is steadied by being strapped on either side to the metal ring on the supporting strap, and its flap should be passed under this strap, between it and the wither pad, and buttoned as in the "Alert" position.

When horses are being sent up to the trenches, the transport or other officer responsible should have the respirators adjusted in the "Alert" position before moving off, as follows: (a) The flap of the respirator case is unbuttoned and slipped under the nose-band of the bridle or halter from

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below upwards. (b) The two straps at the back are also passed under the nose-band and secured to the check pieces of the bridle, on each side. (c) The small unbleached calico patch on the upper side of the mouth of the respirator is buttoned on to the nose-band of the head collar so that the respirator is ready to be slipped on immediately in the event of a gas attack. (d) The cover of the case is then closed over the nose-band, and the respirator is thus protected from rain, and held in position on the nose-band.

The respirator being carried in the "Alert" position is adjusted for use as follows: (a) The flap of the case is unbuttoned and the respirator removed, leaving the case attached to the cheek pieces of the bridle and lying flat on the face. (b) The mouth of the bag is drawn down over the upper lip and upper teeth with one hand on each side of the mouthpiece, slipped into the mouth, and drawn well up to the angle of the lips. (c) The elastic band is seized on either side close to the mouthpiece, and pulled outwards so as to draw the mouth of the bag tight around the upper jaw, above the nostrils, and is then slipped over the poll.

The respirator is now in position and the animal may be worked in it without difficulty or undue distress. The bit and reins are not interfered with in any way.

A double feed bag filled with straw, moss or leaves saturated with sodium bicarbonate solution will make a fair emergency mask.

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APPENDICES

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APPENDIX I

WARFARE GASES

In gas warfare gas is used for four purposes:—(1) When it is desired to produce deaths or minor casualties in front line and supporting trenches prior to an advance. (2) When it is desired to produce casualties in front line trenches, among supports, reserves and other personnel at places where an attack is expected to be made within a few hours. (3) When it is desired to produce casualties in front line trenches among supports and reserves and along lines of communications, in concentration camps, rest areas, etc., to the limit of range of artillery, when no attack is planned or when it will not take place for several days. (4) When it is desired to reach training areas, cantonments, junctions and places beyond the range of guns and which can be reached only by airplanes or balloons.

For technical uses gases are generally divided into three groups:

Persistent. Mustard gas (dichlorethyl sulphide) is the leader of this group and is in a class by itself, due to its excessive persistency, its effectiveness in low concentrations and the fact that it affects the skin, eyes, throat and lungs, as well as the digestive tract if food exposed to it has been eaten.

Non-Persistent. These gases are highly lethal and deadly with low persistency. The group includes phosgene, cyanogen chloride, diphosgene, chlorine and others of a similar nature. Chlorpicrin is in this class, although it is much more persistent than any of the others.

Lachrymatory and Irritating Gases. These include bromacetone, ethyl iodoacetate, brombenzylcyanide, and some other lachrymators, and diphenyl chlorarsine, or sneez-

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ing gas. All these gases are highly irritating or lachrymatory, but are not lethal, except in very high concentrations not often attained in the field. Lachrymators are economical in forcing the use of the mask and are employed for that purpose.

Mustard gas was discovered by Victor Mayer, a German chemist, in 1886. It is a yellowish oily fluid, freezing at about 50° F., and boiling at about 422° F. Its color varies with the solvents and impurities in it. It combines to a certain extent with the steel or iron in shells. It is very highly persistent, that sprayed on the ground being very dangerous for a week or longer in damp, cold weather. It vaporizes very slowly. It has the quality of cumulative effect to a marked degree, being at least 50 per cent. for very low concentrations. If one part in 2,000,000 is breathed for 20 hours it will produce a casualty as serious as one part in 100,000 will produce in two hours. It produces casualties almost entirely by burning, the theory being that the gas in the presence of moisture is broken up so as to liberate hydrochloric acid which produces the burn, and destroys any soft moist tissue it reaches, whether within or without the body. It readily penetrates clothing. The odor of mustard gas is not unpleasant, that of the Germans being somewhat like mustard while that of the Allies was more like garlic. See Chapter IX and Appendix 6.

Phosgene or carbonyl chloride is a liquid boiling at 47° F., with a marked odor, like that of moldy hay. Because of its low boiling point, it will not remain on any terrain on which it is thrown for more than a few minutes. It will form clouds of varying concentration, depending on the manner in which it is thrown over, and a very heavy cloud may render positions dangerous 10 km. from the original point of attack.

Phosgene is sent over by the enemy in cylinders, projector bombs and trench mortar shells. In cylinders it is usually mixed with chlorine in order to form a mixed gas of high vapor pressure. It is generally used pure in the 75, 170 and 250 mm. trench mortar shells and in the 180 mm. smooth-bore projector bombs. In these it is rarely mixed with chlorpicrin. Recently phosgene has been used in long range rifled projector shells mixed

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with pumice, absorption in which retards its evaporation, making it persist for several hours. Finally, it occurs generally in small proportion as a decomposition product of diphosgene in artillery shell for 77 and 100 mm. guns and in the 105, 150 and 210 mm. howitzers.

Phosgene is a lung irritant and is probably the most deadly gas used in warfare. Exposure to high concentrations for even a short time will cause severe casualties, or death, and much lower concentrations will also have serious effects. Its full effect is usually delayed for several hours and exercise after exposure to this gas will render slight casualties much more serious or even fatal. Because of this effect, men who have been gassed even slightly and who have experienced no symptoms of gas poisoning must be prevented from taking any exercise whatever, if serious casualties are to be prevented.

Phosgene is used entirely as a surprise gas, as high concentrations can be developed with it very rapidly. Its persistency is low, and it is, therefore, possible to follow up a phosgene attack with an infantry advance after a very short time. The respirator gives absolute protection against this gas. Troops must be trained to put on the respirator quickly and well, under any circumstances, and sentries must be thoroughly instructed so as to be able to recognize phosgene attacks and to give the alarm immediately. Trenches and dugouts can be quickly rid of phosgene by means of fanning and fires.

Diphosgene, superpalite or trichlormethyl chlorformate, is a liquid boiling at 261° F. Its other properties and action resemble those of phosgene very closely. It cannot be used in cloud or projector attacks because of its high boiling point. It is used mixed with chlorpicrin in green cross 1 shell of different calibers and with diphenylchlorarsine in green cross 2. Phosgene usually accompanies diphosgene in the latter, due doubtless to the decomposition of the diphosgene.

Chlorpicrin is a colorless liquid boiling at 234° F. and hence is fairly persistent. It approaches phosgene in its poisonous effect. Even in very low concentrations it will cause lachrymation and in higher concentrations vomiting, which may necessitate the removal of the mask. The clothes of men who have been exposed to chlorpicrin

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French Number	Shell Filling	American and British Code Symbols	French Designation	German Designation and Shell Marking	Odor
	Chlorine (Used only in cloud gas)	Red Star	Bertholite		Chloride of Lime
4	Arsenic Trichloride 30% Stannic Chloride 15% Hydrogen Cyanide 50% Chloroform 5%		Vincennite		
4B	Cyanogen Chloride 70% Arsenic Trichloride 30%		Vitrite		
	Diphenyl Chlorarsine	D. A.	Sternite	Blue Cross	Slight
	Diphenyl Cyanarsine	D. C.	Sternite	Blue Cross	Is interchan
5	Phosgene	C. G.	Collongite	Three White bands. White D.	Musty Hay, Green Corn
	Diphosgene	Not used S. F.	Superpalite	Green Cross	Disagreeable, suffocating. Musty Hay
	Phenyl Carbylamine Chloride			Green Cross	
	Phosgene, Diphosgene and Diphenyl Chlorarsine			Green Cross 2	Resembles Diphosgene a little pungent
	Chlorpicrin 75% Phosgene 25%	P. G.			Pungent, Suffocating.
	Diphosgene and Chlorpicrin			Green Cross 1	Pungent, Suffocating.
7	Chlorpicrin	P. S.	Aquinite		Pungent
	Chlorpicrin 80% Stannic Cholride 20%	N. C.			Pungent
	Ethyl Dichlorarsine and Dichlormethylether			Yellow Cross 1 or Green Cross 2	Ethereal, Pleasant.
9	Bromacetone Brom Ketones	B. A.	Martonite	Green Cross	Pungent
21	Brombensylcyanide	C. A.	Camite		No Odor
20	Mustard Gas (Dichlorethyl Sulphide)	H. S.	Yperite	Yellow Cross	Slight Mustard or Garlic

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PROPERTIES OF COMMONEST GASES

Persistency		Physiological Effect	Remarks
In Open	In Woods		
Non-Persistent Class			
10 min.	3 hrs.	Lung Irritant, Deadly. Action Immediate.	These gases are very volatile; they are vaporised entirely at the moment of explosion, forming a cloud capable of giving deadly effects, but which loses more or less rapidly its effectiveness by dilution and dispersion into the atmosphere.
10 min.	3 hrs.	Lachrymatory and Respiratory Irritant. Considered quite toxic, but in high concentrations only.	
10 min.	3 hrs.	A Lachrymator, Respiratory Irritant and Lethal Agent.	
10 min.	3 hrs.	Sneezing Gas. Nerve Depressant. Respiratory Irritant.	These gases form non-persistent clouds of solid particles.
geable wit	h D.A.	Effects somewhat greater.	
10 min.	3 hrs.	Respiratory Irritant. Very deadly. Action usually slightly delayed.	
Semi-Persistent Class.			
3 hrs.	12 hrs.	Same as phosgene.	These gases, having moderately high boiling points, are only partially vaporized at the moment of explosion. The cloud formed upon explosion is generally not deadly, but it immediately gives penetrative lacrymatory or irritant effects. The majority of the "gas" contents of the shell is pulverised and projectod in the form of a spray or fog which slowly settles on the ground and continues to give off vapors which prolong the action of the initial cloud. Phosgene in these mixtures has same effect as used above, if concentration is sufficiently high.
3 hrs.	12 hrs.	Eye, Nose and Throat Irritant. Not very poisonous.	
3 hrs.	12 hrs.	Respiratory Irritant. Slightly delayed action. Very deadly. Causes vomiting and a little lachrymation.	
3 hrs.	12 hrs.	Causes vomiting, Respiratory Irritant, a little lachrymation.	
3 hrs.	12 hrs.	Slightly delayed action, very deadly, respiratory irritant, causes vomiting and a little lachrymation.	
3 hrs.	12 hrs.	Causes vomiting, respiratory irritant, tear producer.	
3 hrs.	12 hrs.	Respiratory irritant, causes vomiting, tear producer.	
3 hrs.	12 hrs.	Nerve poison similar to diphenylchlorarsine, easily destroyed by water.	
Persistent Class.			
2 days	7 days	Lachrymator, Tear Producer.	These gases, having very high boiling points, are but little vaporized at the moment of explosion. A small portion of the contents of the shell is atomised and gives immediate effect, but by far the greater part is projected on the ground in the form of droplets which slowly vaporise and continue the action of the initial cloud.
3 days	7 days	Tear Producers, Slight Respiratory Irritants. Action immediate.	
3 days	7 days	Not toxic but most powerful lachrymator known.	
3 days	7 days	Respiratory Irritant. Eye and Skin Irritant. Blistering Agent. Action delayed several hours.	

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are dangerous because of the gas which is carried on them and the same precautions against gassing men in dugouts must be taken as in the case of mustard gas. Chlorpicrin is used mixed with diphosgene in green cross 1 shell. The respirator gives full protection.

Diphenylchlorarsine is a solid of extremely low volatility and is practically odorless. It is used in green cross 2 and in the blue cross shell which contains in addition a large amount of high explosive. On the explosion a cloud of vapor is formed. The cloud will cause headache and intense pain in the throat and chest, accompanied by sneezing and coughing. Vomiting and even temporary paralysis of the nervous system may finally result. It is used mainly to unnerve a man and prevent him from adjusting his mask quickly or to prevent his keeping it on after it is adjusted. It is used also for direct neutralization through the production of the above painful symptoms. The effects of this gas when used alone disappear quickly. The respirator gives absolute protection, but must be put on immediately. Diphenylcyanarsine is similar in its action and rather more effective. It is used in blue cross shell.

Ethyldichlorarsine is a moderately volatile liquid, present in shells whose marking has recently been changed from yellow cross 1 to green cross 3. It is analogous to dipenylchlorarsine in physiological action, exerting a more destructive effect upon the respirator tract along with the nerve poisoning. It is rapidly destroyed by moisture.

Brom-ketones and other gases are used as tear-producing agents. They are heavy liquids with high boiling points and are used usually mixed with deadly gases, in all the various forms of projectiles. They are capable of producing blinding tears in very low concentrations and are particularly effective in forcing men to put on their masks. For this reason they are valuable as harassing gases. They have also a noticeable poisonous effect. They are fairly persistent. The respirator gives absolute protection against them. Chlorpicrin, in addition to its toxic properties, is of value as a tear producer.

Smoke may be used by the enemy, either in the form of a cloud or emitted from shell and bombs. It may be

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used with gas or between gas clouds; it may also be used alone to distract attention from a real discharge of gas, and in general for preventing observation, as for instance as a screening barrage, or for blotting out machine gun nests.

In the tables on pages 202 and 203, the persistency is dependent to a large extent on temperature, wind velocity, and the amount of gas liberated, especially in woods or other more or less closed places. High temperatures and wind velocities decrease persistency, and low temperatures and wind velocities increase it.

APPENDIX 2

CARBON MONOXIDE

Carbon monoxide is not used directly in an attack, but causes a large number of deaths. It is formed when carbon burns or when any high explosive explodes in a confined place, such as the entrance to a trench, mine or dugout. The great danger of this gas arises from the fact that it is colorless, odorless, and nonirritant, and that the onset of symptoms is so insiduous that very often the first warning that a man may receive is failure in the power of his limbs which will prevent him from retreating into safety. Neither the box respirator nor other masks give protection against carbon monoxide; protection can only be attained by the use of special oxygen breathing apparatus. At the autopsy, the blood may be red in color instead of dark if there is a considerable degree of saturation of the hemoglobin with carbon monoxide. If the case has continued to breathe for some time after reaching an atmosphere free from carbon monoxide, this gas will have been partly or entirely displaced from the hemoglobin and the blood after death will have its normal color.

The simplest method of detecting the presence of carbon monoxide in blood is to compare the color of a dilute

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solution of the suspected blood with a similar solution of normal blood. Take a drop or two of blood from the finger of a normal person and dilute it in a test tube very considerably with water (a one-half of 1 per cent solution is a convenient strength), so that when examined by transmitted daylight the color of this solution is a reddish-yellow. Then take a drop or two of the suspected blood and dilute it similarly with water, so that the depth of color of the solution is the same as that of the solution of normal blood when both are viewed by transmitted light. On examining the quality of the color it will be found that the solution made with the suspected blood, if it contains carbon monoxide hemoglobin, is definitely pinker than that made with the normal blood, though it will not have the full pink tint of the same normal blood solution if the latter be shaken with coal gas so as to saturate it quite completely with carbon monoxide. The lungs show no abnormal changes in cases of rapid death. Small punctate hemorrhages may be found in the white matter of the brain and sometimes ecchymoses in the meninges if the case has been exposed to a concentration of carbon monoxide sufficient to cause prolonged unconsciousness.

Except with very massive doses, when loss of consciousness is very rapid, the symptoms develop very gradually, as the gas is only absorbed slowly. If a man is at rest in a concentration of the gas of 1 part in 1,000 it will take about two hours before definite giddiness appears and he will not be definitely disabled until the lapse of two and one-half hours. The rate of absorption of the gas is much quickened when the breathing is deepened during muscular exercise and the exercise also leads to great accentuation of the symptoms. With a concentration of 2 parts in 1,000 a man will be seriously affected in half an hour if he is performing a moderate amount of muscular work, and this concentration may prove fatal with prolonged exposure.

Small animals are far more quickly affected by carbon monoxide than man is, owing to the natural great ventilation of their lungs and the rapidity of their circulation. A mouse or a canary will show definite symptoms of carbon monoxide poisoning in a tenth of the time that a

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man will. If small animals are used to give an index of the presence of carbon monoxide in a suspected atmosphere, it must be remembered that though they show symptoms long before a man feels any effects, the man will in the end be reduced to the same conditions as the animal, and he ought therefore to leave the dangerous atmosphere directly the animal shows signs of being affected, unless he is protected by special apparatus.

The first sign that tells a man that something is amiss is very frequently a feeling of loss of power in the limbs. Giddiness, slight confusion of mind, and breathlessness and palpitation on the least exertion also show themselves. The confusion of mind and loss of power in the legs frequently preclude a man from withdrawing from danger, even though he is dimly aware that safety is only a few yards distant. The failure of power in the limbs and mental confusion rapidly increase and the man may appear drunk, shouting incoherently, laughing, swearing, or praying. Apathy and complete helplessness supervene, and failure of the intellectual powers gradually passes into complete unconsciousness, which may finally terminate in a painless death. The symptoms may remain stationary at any stage, since the degree of saturation of the hemoglobin with carbon monoxide reaches a final end point which is determined by the relative concentrations of the carbon monoxide and the oxygen which are simultaneously trying to combine with the hemoglobin.

The symptoms detailed above are due to the gradual diminution of the oxygen-carrying power of the blood and the exposure of all the organs of the body to increasing want of oxygen. It is clear that any increase in the oxygen demands of the body is to be avoided, and any man, therefore, who shows definite signs of gassing should be carried to a place of safety. If he attempts to walk himself he is quite likely to fall down unconscious. When a moderately gassed case reaches fresh air he sometimes falls unconscious, while other cases may commence to shout and struggle, in which case their movements need to be controlled. Any case showing definite symptoms should be removed as soon as possible to some place of safety where he can remain at rest for an hour or two before evacuation. Rest is essential.

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As carbon monoxide hemoglobin is a dissociable compound, the carbon monoxide is gradually driven out of its combination with hemoglobin by the oxygen of the air as soon as an atmosphere free from carbon monoxide is reached. In fresh air it will take an hour or two before the blood is entirely freed from carbon monoxide, but the process can be rendered five times as rapid by giving the patient pure oxygen to breathe. It is important therefore to begin the administration of oxygen by some efficient method as soon as possible after the case has been removed from the poisonous atmosphere. Administration of oxygen should be kept up as continuously as possible for half an hour to an hour, depending on the severity of the symptoms. It should be remembered that if a case can be kept at rest for half an hour and oxygen administered immediately after being removed from the poisonous atmosphere, he will be in far better condition to travel than if he has to be removed to a more distant point. If the breathing is very shallow, administration of oxygen may be combined with artificial respiration. Collapse should be combated by external warmth and by friction of the limbs.

In chlorine poisoning the pulmonary edema and damage to the lungs and the consequent interference with the gaseous exchange taking place between the blood and the air in the lungs persist for some time and may necessitate the administration of oxygen for several days. In carbon monoxide poisoning the structure of the lungs is not interfered with and oxygen is administered with the deliberate intention of accelerating the discharge of carbon monoxide from the blood. When once this has been accomplished, i. e., after half an hour's or an hour's administration, there is no need to continue the oxygen administration, as the oxygen-carrying power of the blood has now become normal again. Any symptoms that persist are due to effects that were produced while the blood was charged with carbon monoxide and are unlikely to be influenced by oxygen administration when once the carbon monoxide has been got rid of. Further oxygen administration is therefore required only if cyanosis begins to develop subsequently from secondary cardiac or respiratory failure.

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Cases of carbon monoxide poisoning have been known to recover, even when they have remained unconscious for so long as 48 hours after removal from the poisonous atmosphere. In cases that have been severely gassed the possibility of subsequent cardiac dilatation must not be lost sight of, and cases of severe gassing should not be returned to duty until confidence is felt that the circulation has recovered from the strain. As a result of damage to the nervous system while the blood was charged with carbon monoxide, paralysis of single muscles or a group of muscles, or different forms of mental disturbance are sometimes found as sequelæ.

APPENDIX 3

CHLORINE

The effects of chlorine poisoning may be classified under the headings of irritation and inflammation of the respiratory tract, interference with the circulation and general toxic effects. The irritation of the sensory nerves, however, is not the fatal factor. An inflammatory reaction, with congestion of the vessels, edema of the tissues and an abundant discharge of serous effusion through the dying epithelium occurs all the way down the respiratory tract. This begins at the back of the throat; the larynx, with its resistant epithelium, escapes injury, but the damage to the surface tissues increases progressively down the trachea, the bronchi and their finer branchings, and ultimately attains its maximum in the air sacs. The bronchioles are rapidly filled with a serous exudate which passes up into the trachea and is coughed out.

A universal obstruction in this way of the bronchioles alone would suffice to cause death by simple blockage of the airway and asphyxia. But the injury is not confined to the bronchial tree and probably the effusion in the tubes alone is not dense enough to hinder the passage of

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some air up and down, though even this thin fluid may constitute a very serious mechanical obstruction when it is churned up into a continuous foam by violent respiratory efforts. At first there may be so much spasmodic contraction of the muscles of the smaller bronchioles that the gas is denied access to many areas of the lungs. Sooner or later these relax, and the irritant vapors then destroy the pulmonary epithelium, while the air sacs rapidly fill up with inflammatory exudate and become utterly useless for the purpose of respiratory exchange. The edematous effusion must ultimately compress the capillaries and cause great hindrance to the flow of blood through the lungs. The irritation spreads so widely that a blood-stained serous effusion soon accumulates in the pleural cavity, but this is never so abundant as to require aspiration.

In addition to this inflammatory edema, which chokes the circulation and prevents gaseous exchange, there is often some actual damage to the structure of the lungs. The violent coughing and inspiratory efforts which may result from inhalation of the gas may be so forcible that the partitions between the alveoli are torn and air may even burst its way out into the areolar tissue and escape along the hilum of the lung and up into the subcutaneous tissues of the neck. Such disruptive emphysema adds at once to the disability of the sufferer, since it throws out of action that part of the lung which is not yet submerged in the rising flood of edema fluid, and it may lead to permanent shortness of breath if the man survives.

There are four factors which develop in rapid succession and prevent exchange of respiratory gases through the lungs: (1) Narrowing of the bronchioles by spasmodic contraction of muscles in their walls. (2) Disruptive emphysema. (3) Obstruction of the bronchial tubes by exudate. (4) Flooding of the pulmonary air sacs by serous effusion into them. The result of these changes in the lungs, of which (3) and (4) are the most important, is that the intake of oxygen and the elimination of carbon dioxide are seriously interfered with, and the man passes into a state of asphyxial cyanosis in which mental failure and unconsciousness may rapidly supervene. During this state the breathing is labored, rapid,

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and interrupted by spasmodic bouts of coughing. The blue color of the face shows the urgent need for oxygen, and every muscular effort made by the body and by the heart increases that need. Coughing is helpful in so far as it may dislodge exudate from the bronchi, but the violent effort is prodigal of such oxygen as can be supplied and it tends to increase the disruptive emphysema. The increased respiration is caused both by the accumulation of carbon dioxide and by the want of oxygen and not by the absorption of any poisonous substance from the gas. In itself, this increased breathing does no harm and it helps in eliminating CO_2 and increasing the intake of oxygen which are the chief needs of the moment.

The ordinary phenomena in asphyxia of mechanical origin are that the blood pressure rises and that the heart soon loses its full driving power because its muscle cannot maintain this increased effort when it is working with a scanty supply of oxygen. Consequently the pulse rate quickens, the right heart dilates and the blood tends to be pooled up behind it in the great veins. If this failure proceeds apace, a patient who at the beginning showed congestive cyanosis of the face with a full pulse will gradually assume a gray pallor while the pulse accelerates and falls off in power. These changes are present in cloud gas poisoning and they are augmented by the edema of the lungs, which directly obstructs the pulmonary circulation and causes an earlier failure of the right side of the heart. If the patient during this critical time tries to carry on his work and remain standing, he will use up still more rapidly the little oxygen that he is receiving, extra work will be loaded on to a heart which is already overstrained and the circulation will be likely to fail still more speedily on account of the difficulty of maintaining compensation in the upright posture. There is no interference with the respiratory properties of the blood which can at once take up any oxygen that reaches it through the lungs.

Experiments indicate that chlorine is not absorbed from the lungs and that the effects produced by this gas are only a direct and local inflammation with secondary results which are either of a mechanical nature or caused

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by oxygen want or due to a nervous reflex from the seat of injury. Changes of a general nature do undeniably appear in the nervous, circulatory, alimentary, and renal systems of a man who has been poisoned by cloud gas, but these are probably the result of the asphyxia rather than of the direct action of the gas. Thus in the mild cases there is a sense of fatigue and of being altogether done up, and in the serious cases even unconsciousness, but these features are not in excess of what may result from oxygen want. The retching and vomiting that generally occur in the first stages of poisoning may be due only to direct irritation of the back of the throat and of the stomach by the gas, or may be the direct sequence of violent bouts of coughing, while the diarrhea, which sometimes is an early feature, may be that of emotion.

Microscopic examination of the kidneys in death, a few days after gassing, reveals very definite inflammatory and destructive changes, and such kidneys may be swollen and enlarged as though with a parenchymatous nephritis. This change, however produced, rarely leads to any clinical feature of renal trouble. In the first few days the urine contains neither sugar nor albumen nor many casts, and it is very unusual for albuminuria to develop later. The circulation may fail with unexpected rapidity and the patient soon present the aspect of a leaden gray cyanosis. But in general terms the clinical picture with chlorine may be summed up as that of a man suffering from intense irritation of the respiratory tract and dying by asphyxia from the fluid that has drowned his lungs. It does not suggest a deeper toxic action.

In a case of death at 24 hours after gassing, the trachea and bronchi are purple red and congested, while a thin serous exudate wells up into them from the lungs. The latter organs are heavy and edematous, while aërated islets of emphysematous overdistention alternate with depressed purple patches of collapse. On section, serous fluid drips abundantly from the lung tissue. Air that has escaped from ruptured vesicles is seen in chains of bubbles on the surface of the lungs, along the interlobar fissure and even penetrating the tissues of the mediasti-

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num. In some of the earliest cases the most intense disruptive emphysema was observed, destroying the air sacs and interfering with the circulation in their walls.

Petechial hemorrhages appear on the surface of the lungs, on the heart, and also on the inner surface of the stomach. All the veins are greatly distended and the abdominal viscera are engorged with dark blood that clots very early after death. The heart itself may fail to show right-sided dilatation, for this does not of necessity appear post mortem in cases of asphyxial death.

If the man succumbs at a later date, inflammatory complications appear on the lungs. There is superficial pleurisy, scattered broncho-pneumonia, and a purulent secretion in the bronchi. The serous exudate will then be found to have disappeared and no fluid drips from the cut surface of the lungs.

APPENDIX 4

PHOSGENE AND LETHAL GASES

The symptoms of phosgene, chlorpicrin, cyanogen, chloride, diphosgene and other highly lethal gases with low persistency differ from those produced by chlorine in the three following details:

(1) Subjective respiratory irritation is much less in evidence. The men do not suffer with such violent coughing when first exposed to the gas. There is consequently less disruptive emphysema of the lungs, and subcutaneous emphysema of the neck is rare, while post-mortem examination in early cases often fails to find anything more than a little escape of air along the interlobar fissure.

(2) The poisonous effects may appear speedily with cyanotic asphyxia, but sometimes they are more insidious in their onset. A man may feel able to carry on his work for an hour or two with only trivial symptoms; then he rapidly becomes worse and passes into a state of grayish

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white collapse, with progressive edema of the lungs that may soon be fatal. It has even been reported from the trenches that men who have passed through a gas attack and seemed to have suffered but slightly have died abruptly some hours later upon attempting some bodily effort.

(3) Features suggestive of general collapse are more in evidence. There is a much greater tendency to circulatory failure. Many of the cases that die on the first day show a leaden gray tint of the face rather than a purple red cyanosis; the pulse is rapid and of poor tension. Mental confusion or mild delirium with restlessness and unconsciousness become more prominent in the severe cases. No case has been reported of death *immediately* upon exposure to the gas, although men have gone through an attack of gas in high concentration without wearing a mask at all and succumbed in consequence an hour or more later.

The action of phosgene ($COCl_2$) differs from that of chlorine in certain respects. Upon meeting moist surfaces it is broken up and hydrochloric acid is liberated. It excites less spasm than does chlorine in the upper respiratory tract, and so can penetrate to the innermost recesses of the lungs, where it causes an irritant edema which may be a little delayed in its development, like that caused by the acids formed from nitrous fumes, although the delay in the latter case is more prolonged. Experiments do not show that the products of phosgene are absorbed from the lung and act as general poisons apart from their local action.

In a case of death by asphyxia cyanosis where inflammatory effusion had developed with great rapidity the lungs were smaller than normal, heavy, uniformly airless and purple, so that each resembled a big spleen. There was no disruptive emphysema. Thin serous fluid ran abundantly from the surface when cut across. Each pleural cavity contained about 15 ounces of serous effusion. There is no striking difference between the cases which had shown pallid collapse and those which succumbed in extreme cyanosis. The condition of the heart is found to be variable, but there is always evidence in the viscera of vascular engorgement from failure of circulation. The lungs never show voluminous emphysema, and in-

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deed the earlier the death the greater is the serous edema in their substance. On the second day the fluid does not drip quite so freely from the cut surface as on the first, and toward the beginning of the third day the general aëration of the lung is everywhere greater, while relatively large islets of well-aërated and slightly emphysematous lung may be present between areas of edema or collapse. This aërated condition appears at first in the lower lobes of the lungs where they are in contact with the diaphragm, while edema persists longest and is most profuse in the upper lobes. A day later and no serous fluid at all escapes from the cut surface. At this date inflammatory complications tend to appear in a surface pleurisy, and areas of the lung are found to be slightly friable and entering into a condition of broncho-pneumonia.

It may be that cases of extensive and overwhelming edema succumb at once, while those in which on the second or third day larger islets of aërated lung alternating with edematous patches are seen, had from the beginning been in that state, so that they succumbed later than the completely edematous group because the injury to the lung was less. But the general evidence favors a more hopeful view, namely, that the edema fluid is rapidly absorbed from the second day onward, and that the later post mortems illustrate the stage in this recovery. The chief fact in support of this view is that patients who had been deeply cyanosed at first, with the usual signs of extensive pulmonary edema, and so asphyxiated as to be unconscious for a couple of days, may yet recover so completely that eight or nine days after exposure to gas it is difficult to discover any physical signs of edema in the lung.

Upon exposure to chlorine alone, a man feels immediate respiratory distress. He coughs violently and speech is made impossible by his spluttering gasps. With the later forms of drift gas, the onset is slightly altered. There is some lachrymation. The throat feels gripped and the chest tight. Breathing is difficult but not impossible. Coughing develops a quarter of an hour or more later. Nausea and vomiting appear quickly, so that a man who was slow in getting protection may vomit inside his gas mask. Headache and throbbing sensations

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in the body are experienced. Coughing and retching increase. The respiration becomes very hurried and labored, though shallow. The patient's face assumes a cyanotic hue; he may lose muscular power and consciousness and die in an hour or two. Those who survive longer show the following features:

Headache, pain behind the sternum and in the epigastrium. Extreme restlessness and anxiety, or a semicoma with a muttering delirium, from which as a rule they can be roused to answer questions. Varying cough, sometimes slight, sometimes reiterant with a croupous rattling from exudate in the trachea. There is practically no laryngitis. A cyanotic blueness in the lips and ears, which may accompany a flushed lividity of the face or the grayish-yellow pallor of collapse. Extremely rapid respiration, from 40 up to even 80 a minute, of a shallow type on a distended chest, and often marked by a jerking grunt of expiration. A pulse of about 100, which may rise to a higher rate and fall to a very low pressure in the gray examples of collapse. The skin is dry, and either hot or cold in correspondence with the state of collapse. Expectoration may be very slight, though in others there soon develops an abundant discharge of thin watery fluid, often streaked with blood, which simply flows from the mouth as the dying patient loses power to expel it. After death, the foam from this fluid may dry to a white efflorescence around the mouth. The percussion note is slightly flattened over the lungs behind, where the breath sounds are much weakened, but otherwise unchanged in quality. Fine rales are heard behind and in the axillæ. There are no tubular breath sounds. In front there may be extremely little change beyond harshness in the breath sounds. The physical signs fail altogether to indicate the extent to which the lungs are damaged, for in any area examined there is always some aëration of the bronchioles and alveoli which suffices to produce relatively normal sounds on auscultation.

Four-fifths of the deaths occur in the first 24 hours. Very few succumb after the third day. A man, who at first seemed to be lightly gassed, may, toward the end of the first day, develop cyanosis and die; but from the end of the second day onward, there is no danger to be ap-

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prehended for the less grave cases. On the second day the sputum becomes less abundant, more viscous and yellow tinted. The dyspnea persists and the temperature is raised. If complications develop subsequently from infections of the raw respiratory tract, they will be shown by persistence of fever, by a purulent sputum, and by signs of broncho-pneumonic consolidation.

But as a rule the patient recovers rapidly after the third day, and at the end of a week he is fully convalescent. Cough, pain in the chest, which is often very severe beneath the rib margins, shortness of breath, loss of appetite with gastric pain, and general lassitude persist longest of the symptoms. There are no serious after results to be apprehended. A man who has been badly gassed requires a long rest; but the majority, if free from neurasthenic symptoms, are fit for light duty in a very few weeks, provided that they are allowed sufficient rest at first. The heart and circulation are severely strained by gas poisoning. Convalescents who show tachycardia must be carefully watched lest too heavy physical effort early in the first month of recovery induce further strain and lead to the condition of irritable soldier's heart, from which recovery will be long delayed.

In some cases that died after two or three days of persistent cyanosis and unconsciousness the white matter of the brain was found to be peppered with tiny petechial hemorrhages. These are the direct outcome of the asphyxial state and have little clinical significance. Large cerebral hemorrhages have, however, been noted, occurring on the first or second day in cases of plethoric cyanosis.

Men, and especially officers, should be warned beforehand that if lightly gassed they must refrain from moving about or shouting out orders. Physical strain after gassing may easily involve the loss of a life that might otherwise have been restored to the fighting line in a short time. All kit that hinders the play of the respiratory muscles, especially belts and suspenders should be undone. Sleep brings improvement, and restless excited cases should be quieted by morphia. It is important that arrangements should be planned beforehand at each casualty clearing station so that even a large number of

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gas casualties can be handled with such discipline and control as will at once introduce a sense of order and quietude, and by separating those who are more dangerously ill from the remainder, enable the less severe cases to get to sleep at once.

Next in importance to rest comes the use of oxygen, protection from cold, special stimulants or drugs, venesection, and methods for removing serous exudate from the lungs. Bronchial spasm does not seem to be a serious danger with the present form of cloud gas. Life or death is decided by the degree of pulmonary edema and asphyxia with circulatory failure. The edema fluid tends to be absorbed quickly, and if the patient can be carried alive through the first two days, he should recover. Precautions in the meantime need to be taken to lessen the chance that secondary respiratory infections may develop as a later complication.

Oxygen, if rightly administered, will generally lessen cyanosis, and therefore improve the patient's chance of life. But the lung surface available for absorption is so small that the oxygen must be given in high concentration. The simple admixture with air obtained by open flow from a funnel or a tube placed in the patient's mouth is useless, and since it wastes valuable oxygen it should be forbidden. Given as the pure gas from a bag with a valved face mask, say for 3 or 4 minutes every quarter of an hour, an oxygen cylinder of 20 feet capacity will last about 4 hours. By this means life can undoubtedly be saved in some of the apparently desperate cases. The administration must be continued night and day, so as to hold cyanosis in check. The consumption of oxygen by this method is so large that all care must be taken to economize cylinders, the provision of which, under active service conditions is necessarily limited by considerations of transport. Many casualties are so severely poisoned that their condition is seen in the first few hours to be hopeless. Some selection of the cases for oxygen treatment must therefore generally be made, and it is especially with the intermediate group who are surviving into the second day that oxygen has the best chance of acting with ultimate advantage. It is quite unnecessary to use it for relatively mild cases. Deep cyanosis, whether of

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the congestive or pallid type, is the indication of need, and the lividity can almost always be lessened if the face-mask is properly applied.

APPENDIX 5

NITROUS FUMES AND LACHRYMATORS

The great danger of nitrous fumes, nitric oxide and nitrogen peroxide, arises from the fact that in the concentrations usually met with there is comparatively little irritation of the eyes or upper respiratory passages, and a man working in such an atmosphere will not recognize its deadly nature. Air which contains enough nitrous fumes to cause feelings of irritation in the nose or air passages must be regarded as very dangerous. Nitrous fumes are very soluble in water, and the gas may be readily removed from the atmosphere by means of a water spray, whilst a few folds of a handkerchief or a towel wetted with water and tied over the nose and mouth will give efficient protection in the absence of a mask. The possibility of the simultaneous occurrence of carbon monoxide in atmospheres containing nitrous fumes must be remembered.

The pathological changes found post-mortem in a fatal case of nitrous fumes poisoning are identical with those described as characteristic of chlorine poisoning. If the concentration of nitrous fumes to which the case has been exposed is very high, the blood may be somewhat chocolate colored owing to the formation of methaemoglobin. If the gas is in very great concentration, rapid fatal asphyxiation takes place, but in the concentrations that are usually encountered, the characteristics which distinguish this from chlorine poisoning are the slightness of the initial symptoms due to irritation of the upper respiratory passages and delay in the onset of acute pulmonary edema. The typical sequence of events is—

(1) Slight irritation of the nose and throat, feeling of

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constriction of the chest, headache and slight smarting of the eyes and coughing while actually exposed to the fumes.

(2) On leaving the poisonous atmosphere a latent period during which the case may, and usually does, feel quite well and has no hesitation in taking a meal.

(3) The sudden onset after four to eight hours of acute symptoms. These commence with marked and increasing distress in breathing, coughing, and often severe pain in the chest. The cough is at first dry, and auscultation may reveal no moist sounds. This condition is speedily followed by the urgent signs of acute pulmonary edema, and death may ensue in a few hours.

When once pulmonary edema has developed, the treatment should follow the lines laid down for chlorine poisoning. The experience of medical officers attached to mines where nitrous fumes are frequently met with during blasting operations, points to the value of inducing emesis as soon after exposure to the fumes as possible, followed by a dose of such a stimulant as aromatic spirits of ammonia. A case of nitrous fumes poisoning should be under medical observation at the time when acute pulmonary edema is likely to develop and a venesection of from 5 to 20 ounces should be made as soon as there is the slightest sign of its onset. Venesection must not be delayed until the patient's condition is grave and the stage of lividity has been reached, or it will be useless.

The immediate effect of a trace of the vapor of such a lachrymator as benzyl bromide in the air is to cause profuse watering of the eyes, accompanied by smarting. If the concentration is somewhat greater, the smarting and pain in the eyes may become intolerable, so that it is impossible to keep the eyes open. The smarting and watering of the eyes will be quite sufficient to put a man completely out of action, because he is incapable of seeing, but protection of the eyes is easily obtained by the use of goggles.

With increasing concentrations of the vapor, other effects show themselves. The vapor is irritant to the lungs and upper respiratory passages and this leads to a burning sensation in the throat and coughing. Nausea is often present and not infrequently leads to vomiting, ac-

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companied, it may be, by pain in the epigastrium. If it is impossible to withdraw from exposure to the fumes, slight confusion of mind and torpor may show themselves.

Under ordinary conditions the symptoms do not develop further, and though the case may become somewhat collapsed as a result of the vomiting and general discomfort, this is only temporary, and within an hour or two after getting into air free from the lachrymator there may be very little amiss with the man. The nausea and irritation of the throat soon pass off, though the eyes may remain sore for some little time, and even after the lapse of 12 hours redness of the eyelids and slight injection of the conjunctiva may still be evident. There are no subsequent toxic effects and the case will be fit for duty as soon as the primary effects have passed off.

It must not be forgotten that some of the acute lung irritants are also extremely powerful lachrymators, and that such substances may be used with a view to securing a double effect, viz., immediate blinding and simultaneous intense toxic effect on the lungs. In order to secure such an effect it is essential that the substance used shall be gaseous or shall vaporize with sufficient rapidity to attain a high enough concentration in the air to produce these intense toxic effects. Lachrymators such as benzyl bromide, which are liquid at ordinary temperatures, vaporize too slowly to produce such a concentration. The smell of benzyl bromide when in great dilution suggests the flavor of mustard and cress. Lachrymators as a rule have aromatic, pungent odors.

When in sufficient concentration hydrocyanic acid acts as a very rapid and sometimes almost instantaneous poison, affecting directly the central nervous system. The symptoms follow one another in rapid sequence: Giddiness, confusion, headache, indistinct sight, palpitation and pain in the chest and over the heart. Labored respiration. Unconsciousness, convulsions, failure of the respiration and finally of the heart. In large doses, immediate unconsciousness, dilatation of the pupils, a few gasping respirations, and death with or without convulsions. The gas paralyzes the respiratory center very quickly, and with small fatal percentages the heart may continue to beat for a brief time after the respiration has ceased.

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With larger concentrations the heart may be stopped almost at once by the direct action of the poison. When death is caused by inhalation of hydrocyanic-acid gas, it is unlikely that the smell of the gas will be detected at autopsy, as may be the case when poisoning is due to the ingestion by the mouth of a large dose of prussic acid.

Immediate treatment is the only measure of any avail if a man falls unconscious from hydrocyanic-acid poisoning. The case must be at once dragged into fresh air, and if the respiration has stopped, or is very weak and gasping, artificial respiration must be instantly applied by Schafer's method.

APPENDIX 6

MUSTARD GAS

Dichlorethylsulphide, known as mustard gas, Yperite or Yellow Cross gas, is an oily liquid boiling at 422° F. On account of its high boiling point, it vaporizes very slowly, and is therefore, extremely persistent. It is a stable compound, being but slowly destroyed by water at ordinary temperatures, more quickly by alkalies such as bicarbonate of soda. Chloride of lime will destroy any mustard gas, either liquid or gaseous, with which it comes in contact. The liquid will soak into soil on which it is thrown and remain there from a week to a month. Therefore mustard gas shell holes should not be dug up for a considerable time after a bombardment. The liquid which remains in or above the surface layer of the soil will slowly vaporize under the heat of the sun. This vaporization will not as a rule be great enough at night or during cold weather to produce dangerous concentrations of gas, but as soon as the ground is warmed by the sun, troops passing near will be in almost as great danger from the gas as at the time of the bombardment. Mustard gas also has the property of remaining on and penetrating woolen and cotton fabrics. Rubber is penetrated

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fairly rapidly. Oiled fabrics delay penetration to a considerable extent. However, it is unwise to depend on this protection for more than a few hours.

The Germans use mustard gas in shell for 77 mm. gun, and for 105 mm., 150 and 214 mm. howitzers, more rarely in 100 mm. and 150 mm. guns. The distinguishing mark is a yellow cross on the side or base of the shell or both. The filling is dichlorethylsulphide, usually mixed with a solvent: carbon tetrachloride, chlorbenzene, or nitro-benzene. These shells have been generally provided with a medium bursting charge, although the use of yellow cross shell with a high bursting charge, simulating high explosive shell, is increasing continually. These latter are marked with a yellow Lorraine cross. The charge in the Lorraine cross shell is of sufficient size to produce a spray of very finely divided particles of the liquid and in this form, though less persistent, the gas is more concentrated and dangerous.

The following points should be carefully noted in regard to this gas, as they, in combination with its persistence, make it the most dangerous of all. Unlike others, it has very little immediate irritating action on the respiratory system or in the eyes, and, therefore, does not force a man to put on his respirator. Exposure to either liquid or vapor, even in low concentration, will cause irritation of any tissue with which it comes in contact. This iritation is usually not noticed for from 3 to 12 hours after the exposure and may affect any part of the body. The worst mustard gas cases are due to irritation of the respiratory tract, which is often serious enough to cause death. A secondary effect is often pneumonia or in lighter cases bronchitis and an acute sore throat lasting for several weeks. Exposure of the eyes to the vapor will cause temporary blindness, which is very painful, and will last from a few days to several weeks, depending on the length of the exposure. The third effect, from which mustard gas derives its name of vesicant or blistering agent, is the production of painful burns on those portions of the skin with which it comes in contact, particularly the tender and moist parts under the arms and around the scrotum.

Mustard gas is used rather as a neutralizing than as a

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surprise gas, because its slow evaporation prevents the rapid formation of high concentrations. Its persistency is greater than that of any other gas, and hence by its use any position may be made untenable for days after it is shelled. It is particularly valuable for use against valleys and woods, because such terrain will remain infected longer than open country. It is used in general against artillery emplacements, support and reserve positions, command posts, billets, woods, communicating trenches and roads. The following translation of a captured German document is instructive:

Bombardment with yellow cross shell will be executed preferably between one and four A. M. At first the bombardment will compel the enemy to wear his mask. A few hours later, when the presence of the gas is no longer revealed by the odor, the enemy will probably take off his mask, but will be overcome later, when the sun rises, by the action of the evaporation. Every attempt of the enemy to nullify the effects of the night gas bombardment in the morning should be neutralized by volleys of rifle, machine gun, minenwerfer and artillery fire.

Mustard gas is rarely used during the three or four days preceding a large scale "push," except against those points over which it is not intended to advance. Particular care must be taken in occupying terrain captured from the enemy because of the danger from gas traps left during his retreat. Gas shell and bombs may be left in dugouts or farmhouses and fused to explode when the locality is filled with our troops. Mustard gas may be sprinkled on roads and at all points over which troops must pass. All shelters will in general have been liberally soaked with mustard gas.

The respirators in use by the American forces give absolute protection against all but the blistering action of mustard gas. Certain special precautions in their use must be observed. Because of the slight odor and delayed action of mustard gas, troops must be trained to put on the respirator immediately when any odor is noticed which *might* be that of gas. They must not remove the respirator until all traces of the gas have disappeared. They must be trained to wear it for long periods of time and to be able to work efficiently while wearing it. Men

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who have been exposed to mustard gas and have been *testing for it for several hours,* gradually lose their ability to detect it. On wearing the mask a short time one recovers his keenness of smell for the gas.

Sag paste is a protective ointment which, if applied before exposure to the gas, will greatly diminish its effects upon the skin. The paste should be rubbed liberally in an even layer on the genital organs and region, the buttocks, the armpits, and other parts of the body which perspire freely. The length of time that such an application is effective depends entirely upon the strength of the gas. Since there is no way of judging this easily in the field, care must be taken to use a sufficient quantity of the paste and to renew the application about once every 12 hours when continually exposed to the gas. It should be carefully noted that sag paste must be applied before troops enter an area that is likely to be shelled. This will have to be done on the judgment of the unit gas officer.

Any portion of the skin which has been splashed by the liquid from mustard gas shells or even moist parts that have been exposed to the vapor should be washed as quickly as possible with soap and water. Any kind of soap will answer and cold water is satisfactory. It is only necessary to work up a good lather and massage the place well with this lather. Very little water used in this way often suffices to prevent burns. If chloride of lime is available, as it should be, some of the dry powder sprinkled on the skin that is splashed with mustard gas liquid will prevent a bad burn. The powder is to be left on the skin about fifteen minutes and then washed off with water and soap if obtainable.

In general, the best protection against mustard gas is evacuation of all ground infected by it, *if the tactical situation permits,* and *alternative positions should be prepared or selected in advance.* If a zone has been evacuated after a mustard gas bombardment, sentries should be posted on all roads and paths entering this zone to warn troops away from it and to prevent their entering. Sentries should also be posted in front of contaminated dugouts in a zone otherwise free from mustard gas. If not possible to evacuate, frequent reliefs, or protection of troops as far as possible in gasproof dugouts will alone

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prevent numerous casualties, as mustard gas will outlast the staying power of troops wearing the respirator. In connection with the use of gasproof dugouts, it should be noted that men entering such dugouts have gassed the occupants by the gas which they have brought in on their clothes and, therefore, all outer clothing should be removed in the entrance to the dugout and soles of shoes treated with chloride of lime. A scraper, water, and box of chloride of lime should be kept near the entrance to each dugout. The shoes are first dipped into the water, then thoroughly rubbed in the lime, and finally washed off in the water. This precaution, if followed by thorough washing of the body, will be very effective in preventing burns. It should be noted that the enemy will probably not knowingly attack across an area recently shelled with mustard gas.

After a mustard gas bombardment, the covering of shell holes with chloride of lime will render such shell holes harmless. The chloride of lime should be spaded in well, then covered with another thinner layer of lime which is in turn covered with fresh earth. This should be done by a special disinfecting squad provided with the proper protective clothing. It is manifestly impossible in the case of an extensive bombardment to disinfect all shell holes in this way, but those near which troops pass or near dugouts should always be disinfected. Men after walking over an area infected with mustard gas will find it necessary to destroy the poison on their shoes before entering a dugout, as this liquid readily evaporates afterwards in the dugout, rendering the atmosphere extremely dangerous. Chloride of lime is placed on the ground outside of dugouts, in order that the men may use the lime to destroy the liquid that may be carried upon their shoes. There is an element of danger in the use of chloride of lime to destroy gas due to the fact that the odor of the former completely masks that of the latter. When chloride of lime is thrown on liquid mustard gas, some chlorine is given off. This will cause little annoyance. However, the heat of the reaction may vaporize some of the mustard gas which has not yet been destroyed. When large puddles of the liquid are encountered, they will first be sprinkled with sand, dry earth or

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ashes, to absorb the greater part of the poison before being treated with chloride of lime. Clothes which have been gassed can be disinfected by washing in running water for several days, by washing in nearly boiling water for 1 to 2 hours, by steaming for an hour, or by hanging them out in the rain. The extent of cleaning necessary and method employed will depend on the amount of contamination and the conditions in the field. See Chapter IX.

APPENDIX 7

GAS ATTACKS

The enemy employs gas for two purposes—to inflict casualties and to reduce the fighting efficiency of his opponent. For the purpose of inflicting casualties he relies upon surprise, and upon taking advantage of ignorance, bad discipline, faulty training and defective respirators. To reduce fighting efficiency of our forces he seeks to compel the wearing of masks or to employ other protective appliances.

In making a gas attack the enemy seeks to generate a cloud of gas either directly within our own lines or in such a position that it will be carried by the wind into our lines. To accomplish this end he employs three distinct methods:

Cylinder Cloud Attacks. Such attacks are employed more frequently in trench warfare than in open warfare, as there is more time to place the cylinders in the trenches and the stability of movement allows the cloud to drift over the opponent's trenches.

Projector Attacks. Such attacks are limited to a stabilized front in which time and other circumstances permit the projectors to be brought up and placed in position for firing. Improvements to avoid digging trenches to emplace the projectors and more rapid means of transportation will broaden the use of this form of attack.

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Borbardments with Artillery or Trench Mortar Gas Shell. Such attacks are applicable in all modes of warfare.

In the case of cylinder attacks, a highly poisonous liquefied gas of low boiling point is liberated from cylinders placed in or near the front line. In case of projector or trench mortar attacks, and of attacks by artillery shell, the gas is inclosed in a suitable projectile and is thrown into the adversary's territory. There, by means of a percussion or a time fuse and a bursting charge, the shell is broken open and the poisonous material is liberated. The bursting charge is varied, depending upon whether the "gas" is a liquid, or a solid. The bursting charge is usually very small in the case of a liquefied gas, but often sufficient to give practically a high explosive effect, in the case of solids. A liquefied gas vaporizes when the pressure is released by the breaking of the shell, while solids are either atomized or vaporized by the explosion of the bursting charge.

Cylinder Cloud Attacks. Gas clouds are produced by the sudden liberation of a liquefied gas from cylinders in which it is stored under pressure. The gas used is generally chlorine, phosgene, or mixtures of chlorine with phosgene or chlorpicrin. Formerly cylinders were as a rule dug in at the bottom of the trench and connected with outlet pipes that led from the bottom of the cylinder out over the trench parapet. Now they are often piled on trucks or flat cars and fired simultaneously by electricity. When the outlet valves are fully opened, whether by hand or electrically, the liquid is driven out as a gas in two or three minutes, which, mixing with the air forms a cloud. This cloud may vary in appearance, due to weather conditions or to smoke mixed with it. It may be almost transparent and slightly green in color, or it may look like a thick mist.

The cloud is carried by the wind over the opposing line and at times the gas has been noticeable in the rear areas as much as 10 miles from the front line. Gas clouds are usually slightly denser than the surrounding air and therefore tend to fill up trenches and hollows and penetrate unprotected dugouts where the gas remains long after the main cloud has passed. Such clouds tend

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to follow the course of valleys. Lakes or streams do not affect the gas. The chief dangers from such an attack are due to the high concentration of gas at the moment of its release and to the extent of the area which may be covered by the gas under favorable conditions. However, cloud gas attacks are very dependent on wind conditions and should not be made in heavy rains. They are best made only when upward-moving currents of air are not present, that is, when the sun is not shining. They offer a little less chance for surprise than other forms of attack.

During the discharge the warning is often given by the hissing sound of the escaping gas, the appearance of the cloud, and the odor of the gas before the main cloud reaches the trenches. Gas cloud attacks are feared as a dangerous form of attack and when they are made, every form of gas defense equipment is given a most severe test. A later development is the use of portable gas cylinders fired by electricity while lying on the ground.

Projector Attacks. The enemy makes use of "gas projectors" having a range of about 1,500 meters and in the case of the new rifled projectors of about 3,000 meters. By this method a large number of projectiles, each containing about 16.5 pounds of liquefied gas are simultaneously shot from smooth-bore or rifled iron tubes dug into the ground or set in wooden racks. The propelling charges are varied according to the range desired. The electric current for firing the charges is generated by hand-driven magnetos called "exploders," each of which fires about twenty-five projectors. On impact, or by means of a time fuse, the projectiles are exploded and the gas volatilized. By this method, the enemy is able to generate a cloud of gas within our lines. His tactics are not so dependent upon weather conditions as when cloud attacks are made. Projector attacks call for the highest degree of gas discipline among the troops affected because of the surprise which is often secured and the instantaneous formation of an extremely concentrated and deadly cloud of gas. Warning of an impending projector attack may be given by: (a) Noise of installation of the apparatus and material. (b) Active wind observa-

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tions on the part of the enemy. (c) Airplane photographs of projector emplacements, new dumps and tracks.

When the shoot occurs a large flash or series of flashes may be seen in the enemy's lines, followed by a loud explosion, like that of an ammunition dump blowing up. The enemy often tries to conceal this sheet of flame by installing projectors behind hills so that the only warning given is the crash. Sentries should be warned to give the alarm when any sound is heard which *might* be interpreted as being caused by projectors. The course of the projectiles through the air is often seen by the trail of sparks emitted from the time fuses, and the bombs make a loud whirring noise described as being similar to the noise of partridge in flight. In the case of the rifled projector shell the noise is less distinctive and similar to that caused by ordinary artillery shell. Twelve to twenty-two seconds warning is usually given by the flash and explosion.

Gas Bombardment with Trench Mortars or Artillery. The enemy also employs toxic substances in the projectiles shot from trench mortars or minenwerfers. With sufficient rapidity and accuracy of fire, it is possible for him to generate a heavy cloud of gas within our lines. A higher degree of accuracy is attained than with projectors and the bombardments can be continued indefinitely, whereas a projector can be fired only once during a considerable period of time. However, it is not possible by the use of minenwerfer to develop as high a concentration in as short a time and the likelihood of surprise is not so great.

The use of toxic substances in artillery shell is the most important method of gas warfare. Batteries firing rapidly and accurately against some objective, such as another battery, can develop a moderately high concentration at a long range. Owing to the greater range and accuracy of artillery fire, weather conditions affect this use of gas less than others, although a wind of high velocity or upward currents will disperse a cloud of nonpersistent gas so rapidly that very little damage will be done. Gas shells are used in various ways, according to tactical result desired. To produce casualties, sudden

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bursts of lethal shell are concentrated on small targets, and in preparation for an infantry advance enormous numbers of shell containing penetrating and surprise gases are often employed. Harassing fire with persistent gases like mustard, a few shells at a time, may be continued indefinitely against permanent positions.

Toxic substances find a use of minor importance in hand grenades. In this form, the enemy employs poisonous chemicals for the purpose of "mopping up" recently captured trenches and dugouts.

The following is a convenient form to be used for making reports on gas attacks:

AMERICAN EXPEDITIONARY FORCES

Defense Division, Chemical Warfare Service

REPORT ON GAS ATTACK

Serial No.....
(Date of Report).....
Corps .....
Division .....
Unit .....Location .....
From ..... M ....., 19..., to ..... M....., 19....
Method of attack (shells, cylinders, projectors).....
No. of projectiles.....Caliber .....Gas used.....
Wind direction.....Velocity ....M.P.S.....Temperature ..... Humidity .....
Character of terrain (woods, sloping ground ravine, swamp, etc.).....
Area of terrain and length of front affected.....
No. of troops exposed.....
Duds found at (Coördinates)....No.....Caliber.....
Markings .....
Total casualties including deaths.....Total deaths.....
Lung cases..... Eye cases or burns.....
Causes of casualties (approx. No. from each cause; failure to put on mask, premature removal, etc.).....
Length of time respirators were worn.....
Was any part of gassed area evacuated?.....

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At what time?.....
Was attempt made to relieve units required to remain in sector? .....
At what time (in the case of mustard gas) was disinfection of ground begun?.....
Completed .....
Remarks: (should include any new tactical use of gas, any suggestions, etc.) .....
.....
Signed.....

APPENDIX 8

DEFENSE AGAINST GAS

A system of defense against gas must necessarily be wide in its scope and continuous in its action, and on the other hand there is no type of enemy warfare which can be as successfully resisted as gas. Against well-disciplined troops, some of the most violent gas bombardments have failed to secure a single casualty, though any laxity is sure to result in more or less serious losses.

It is the duty of commanding officers to familiarize themselves with the nature of gas, and the means of defense against it. The protective appliances are constantly being improved as gas warfare develops, and when rightly used, they give very complete protection against all forms of gas. In warfare, any substance which is used for its poisonous or irritating effect may be called a gas, regardless of whether it is a "true gas," a mist of fine drops, a cloud of poisonous dust, an ordinary liquid, or a solid.

There are two groups of warfare gases. The first group, of which chlorine is an example, consists of substances that are true gases under ordinary conditions and form gas clouds immediately upon opening the container in which they are stored. Those of the second group, typified by mustard gas, form vapors only very slowly

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unless scattered by shell explosion or warmed by the heat of the sun. *Even an extremely small amount of certain gases if breathed sufficiently long, will cause a casualty.* A man some distance from a shell hole containing poisonous liquid may become a casualty through inhaling the vapor or by its condensation on his body, even if no shell have fallen for several hours. It is important that this be explained so that the men may appreciate the danger of gas, and at the same time realize that there is nothing mysterious or supernatural about it.

In order to cut down gas casualties to the absolute minimum, the following measures must be taken: (a) Thorough training and drill of troops in the use of protective appliances so that they can adjust them accurately under all conditions and perform all duties while wearing them. (b) Frequent and rigid inspection of all protective equipment. (c) Absolute obedience to regulations in regard to carrying the respirator in danger and alert zones. (d) Training all troops to recognize gas attacks. (e) Installation of adequate gas alarms and instruction of sentries in their use. (f) Teaching all officers and gas non-commissioned officers the properties of enemy gases, proper methods of defense against them, and action to be taken in situations likely to arise. (g) Practice in wearing respirators for long periods. (h) Wearing respirators as long as gas is present.

Experience has shown that numerous casualties occur through failure to warn men promptly when the enemy makes a gas attack. *Officers are responsible that arrangements are made for the communication of the gas alarm to all ranks under their command in the shortest possible time.* The need for quickness in giving the gas alarm is imperative; a few seconds delay, particularly in the case of projector attacks, makes a great difference in the number of casualties. *Sentries must be posted over all men sleeping in dugouts.* Whenever there is danger of projector attacks, men should be prevented from sleeping within 1,500 yards of the enemy front line, if tactical requirements permit. On detecting the presence of gas, sentries shout "gas," put on their respirators and immediately spread the alarm in every possible way.

The method of giving the alarm varies with the nature

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of the attack. In cylinder and projector attacks it is necessary to warn troops over extensive areas, which may be traversed by a dangerous concentration of gas, while the effect of gas shell bombardment is much more local, and it is necessary to alarm only troops in the immediate neighborhood of the bombarded area. Any device may be used as an alarm for gas attacks which gives a loud and distinctive noise, and does not require the use of lungs. Improvised alarms, such as church bells and empty shell cases are in use, as well as Klaxon horns, wooden rattles and steel triangles. Such light signals as may be approved by Division Commander on recommendation of the Division Signal Officer and which do not conflict with those already in use, may be employed for gas alarms. Commanders of companies on the move should make sure that a sufficient stock of portable alarm devices is always on hand.

The protection of dugouts against gas has proven of great value especially in the case of gas of high persistency, which may necessitate the wearing of the respirator in an area for long periods. The entrance to all dugouts and shelters of sufficiently good construction within the "Alert" zone should be provided with two gas tight doors, or with two curtains of gas proof material with a space of several feet between them, thus forming a gas lock. Each curtain should be fitted so as to give a tight joint over the whole frame of door, stopping all draughts. Not only should dugouts and cellars be provided with frames and blankets, but care must be taken that the cracks between the frames and the earth or rock walls are made gas tight. Curtains should always be kept moistened or oiled and rolled up when not in use. Unless this is done, the curtains are useless. All dugouts which have been made really gas proof, are posted with a sign "Gas Proof." In medical and signal dugouts particular care should be taken to provide this protection so that officers and men can work during gas attacks without wearing respirators.

Precautions to be observed in dugouts in case of gas attacks are as follows: (a) Lower curtains immediately. (b) Wake all sleeping men. (c) Put out all fires. (d) Stop up any holes or flues. (e) Prevent passing in and out as much as possible. (f) In case of passage in or out,

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only one man must pass through at a time. Only one curtain must be raised at a time, and curtains must be lowered as quickly as possible. (g) Men entering from gassed areas must remove outer clothing and leave it in the gas lock.

After a cloud attack some of the gas will remain in unprotected dugouts, trenches and hollows in the ground. A certain amount will also be absorbed in blankets and clothing. Any gas present in the air may be removed rapidly by ventilation. In shallow dugouts and trenches, fanning with coats or empty sand bags will produce a sufficient draught for this purpose, but all dugouts are cleared most rapidly and effectively by means of a fire. In dugouts provided with a single exit, the best results are obtained if the fire is placed in the center of the floor of the dugout. In those provided with two or more exits, the fire should be placed at the inner end of the exit passage farthest from the wind.

After a bombardment with mustard gas, in addition to gas remaining as described above, some of the liquid will remain on the ground near the shell craters, on the floor and walls of dugouts and emplacements that have received direct hits, in piles of straw and rubbish, in straw mattresses, clothing and equipment. This liquid may continue to give off gas for long periods and every possible means must be taken to destroy it immediately. Pumice soaked in phosgene should be covered deeply with earth (not chloride of lime), or the position evacuated until it ceases to give off gas.

There have been cases reported of food which has been exposed to gas causing ill effects. All food and water should be kept covered. No food that has an unusual taste or odor after a gas attack or bombardment should be eaten. Casualties have more frequently been produced by the use of contaminated water from shell craters. All water from shell craters should be regarded as dangerous until proved to the contrary, and every effort should be made to use water from other sources. Blue Cross, containing arsenic, dissolves in water, making it highly poisonous, and this is not remedied by boiling.

Many gases, particularly phosgene and chlorine, have a corrosive action on metals. This action is greatly as-

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sisted by moisture which dissolves and retains the gas so that corrosion continues until the surface is cleaned. Mustard gas liquid will also corrode brass. Metal surfaces which are covered with mineral oil are not affected, provided they are cleaned and re-oiled after exposure.

The Division Commander is responsible for the proper training and instruction of his command in gas defensive measures. The presence or absence of gas casualties under a gas attack forms a basis for estimating the efficiency of his command. The Chemical Warfare Service provides the division and corps gas officers with suitable samples of the various kinds of gases, especially those of most frequent use, for instructing the personnel in the identification of the presence of gases. These samples are prepared in such form that they may be easily transported without the necessity of increasing the allowance of transportation authorized for moving gas supplies. When in training areas, quantities of various gases are supplied for the purpose of infecting areas and shell holes as they occur under actual conditions of warfare.

Organization. Commanding officers of all units are held responsible that all the anti-gas appliances for protecting their men are maintained in perfect condition, and that all ranks under their command are thoroughly trained in the use of these appliances, and in all measures which may affect their safety against gas, including identification of the presence of gases and the identification of gas attacks.

Battalion, regimental, division gas officers and assistants are appointed to aid in seeing that all anti-gas measures are efficiently carried out. It is their duty to bring any efficiency in gas discipline or protection to the notice of the proper commanding officer when necessary.

A gas officer is appointed by the unit commander for every regiment, for every battalion and for separate units; a gas non-commissioned officer is assigned as assistant to each of these gas officers, and two gas non-commissioned officers are appointed for each company. All gas officers and gas non-commissioned officers are relieved from all duties which might interfere with their duties as gas officers. These gas officers and gas non-commissioned officers, as well as other officers and non-commissioned

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officers chosen for their replacement, are selected on account of their special qualifications. They are required to take a course of training to fit them for their duties.

Regimental and other commanding officers consult their gas officers before relieving the gas non-commissioned officers serving them in order that other non-commissioned officers, properly instructed, may be selected as replacement.

The commanding officers of units are responsible, not only for the gas discipline of attached troops, such as machine gun companies, detachments of engineers and field signal men operating within their areas, but are also responsible for the gas training of these troops, and see that they receive training in gas defense equivalent to the training given their own units.

Gas non-commissioned officers in such attached troops are reported to the gas officer of the unit to which they are attached (battalion or regimental). In case of detachments which are smaller than a platoon, and which have no gas non-commissioned officer of their own, one of the gas non-commissioned officers of the unit with which they are being rationed, is assigned to them to act as gas non-commissioned officer, in addition to his duty with his own company.

Training and Inspection. In addition to training at the schools and in the training areas, all ranks whose duties require them to enter the "Danger" zone should continue respirator drill as may be directed by the Division Commander. Respirators must be worn at least four hours each week, but during this time usual drills and other duties should be performed. Once each month all combatant troops should wear the respirator for four consecutive hours. Respirator drill should include the adjustment of the respirator while the helmet is worn and also the adjustment and wearing of the respirator in the dark.

Respirators, alarm systems, protected dugouts, and such other gas defense measures as may exist under varying conditions within a divisional area, should be inspected twice each week by the proper gas officers. In the "Alert" zone company commanders will provide for similar daily inspection by the gas non-commissioned officers. Any deficiencies should be called to the attention of the company

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commander concerned, and of the battalion commander. As many dugouts as possible should be made adequately gas proof. No dugout curtains or other devices apparently protecting against gas should be maintained in dugouts which are reported not to be adequately gas-proof.

APPENDIX 9

FUNCTIONS OF GAS OFFICERS

The essential qualities of a gas officer are technical knowledge, tact, courtesy, initiative, ingenuity, and energetic perseverance. He must bear in mind that his supply and administrative duties are not the most important, and that one of his most important duties is to advise with respect to gas offense operations. These duties cannot be properly performed from an office in the rear.

The following enumeration of functions of corps and division gas officers is suggestive and not all inclusive:

Administration. (a) Secure and employ as near full allowance of officers and enlisted men as practicable in corps (or division) office. (b) Keep lists up to date of regimental and battalion gas officers and non-commissioned officers. (c) Study the personality of subordinate gas officers. Attempt to make the best use of them by suitable assignments, and to correct faults and weaknesses when possible. (d) Departmentalize, as far as practicable, the work of the corps (or division) gas personnel. (e) Place all enlisted personnel immediately under a responsible non-commissioned officer in charge of office. (f) Secure, if practicable, separate quarters for enlisted personnel. (g) Know by name and rank each officer on the staff and the nature of his duties. (h) Insure that the required number of regimental and battalion gas officers and non-commissioned officers are trained at proper schools. Maintain a written record of training of gas personnel, commissioned and non-commissioned, and their ability, recommending advance of those who discharge

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their duties satisfactorily whenever a vacancy exists. (i) Secure as near full allowances of transportation as practicable. (j) Maintain a filing system, emphasize care of and making of maps, form and substance of reports and correspondence, appearance of office. (k) Keep a war diary.

Relations within corps (or division). (a) Maintain an intimate liaison with all staff departments. (b) Cultivate interest in gas among all officers by congenial, unobtrusive methods. (c) Request action of G-3 on reports and recommendations relating to gas discipline, training and supplies. (d) Secure official publications of necessary orders, such as zone regulations. (e) Secure coöperation of Military Police in enforcement of orders relating to gas defense. (f) Secure all necessary information, such as maps, reports and circulars concerning enemy operations from G-2 (intelligence), concerning our own movements from G-3 (Operations), concerning casualties from the Corps (or Division) Surgeon's office, concerning casualties and our own posts of command from the Statistical Office. (g) Coöperate with representative of Inspector General and Medical Gas Officer.

Operations. (a) Furnish counsel in gas matters as requested by the Commanding General, Chief of Staff, G-3, or (Corps) Artillery Officer. (b) Act as liaison between gas troops operating in corps (or division) area and corps and division staffs, establishing understanding on the part of the staff and an appreciation of their potential value. The Division Gas Officer will aid in establishing similar relations between gas troops and units with which they are to act in the line. (c) Furnish gas troops with all available information concerning suitable targets and movements involving the possibility of activity on their part. (d) Devise plans for use of gas, submitting them to G-3 or to Commanding Officer of Gas Troops concerned where his organization is affected. (e) Establish relations with artillery brigades (or brigade) cultivating interest in gas. (f) Maintain liaison with Munitions Officer and Artillery Operations Officer, also Salvage Officer, and be cautious in recommendations of artillery gas programme, leaving all matters of recommendation which are exclusively in the field of artillerists. (g) Report without

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delay direct to the Army Chief of Chemical Warfare Service all gas offensive operations executed by troops of the division (or corps), submitting a copy of such report to G-3.

Supplies. (a) Study carefully the means of supply and probable future needs of the division (or corps). (b) Insure an adequate supply of timely requisition on the nearest advance army depot, but keep the stock in corps park or division dump as small as compatible with local needs. (c) If not near an advance depot see that requisitions on the base or intermediate depots are placed with G-4 of the army in ample time to secure supplies.

Subordinate Units. (a) Under such instructions as may be issued from headquarters, make periodic inspections with a view toward determining the state of gas discipline, training and supplies, reporting defects to the Division (Regimental) Gas Officer and Commanding Officer of unit concerned. When corrective measures are not applied, submit a special report to G-3 for information of the Commanding General. (b) Keep the Commanding General advised of the state of gas training, discipline and supplies in divisions assigned to corps (or units within the division. (c) Advise next senior Gas Officer on same subject, sending copy of such report to the Chief of Chemical Warfare Service. (d) Assist the Division (Regimental and Battalion) Gas Officers by counsel and suggestion. (e) Study the conditions within divisions (regiments, etc.) through routine report and personal interview. (f) Encourage criticism and suggestion from Division (Regimental and Battalion) Gas Officers. (g) Be watchful at all times of gas personnel who, through temperamental or other unfitness, tend to bring the Chemical Warfare Service into discredit and recommend to the Chief the transfer of such officers and men to other work. (h) Insist upon the use of proper channels of communication. (i) Accustom troops to the use of smoke, high explosives, and thermit by gas troops through demonstration and brief lectures.

Corps Troops. (a) Maintain gas discipline, training and supplies. (b) Undertake training of gas non-commissioned officers in the units not as a whole identified with front line activity (such as remount squadron, etc.).

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(c) Check closely situation concerning replacement battalion and the sending of replacements to the line without proper anti-gas equipment. (d) Interview gas officers and non-commissioned officers of corps troops frequently for purpose of securing from them helpful suggestions and criticism.

Casualties. (a) Keep an accurate account of casualties noting particularly causes, avoidability, fatigue and malingering cases, the nature of gas responsible for casualty, tactical use of that gas, ratio of shell to casualties. (b) Analyze periodically the proportion of casualties attributable to the several gases as indicated by symptoms and recollection of patients respecting smell and appearance of gas. (c) Submit report to Commanding General through G-3 when facts and findings justify. (d) Coöperate with Medical Gas Officer in securing data concerning methods of relief of gas affections and in giving them publicity within the corps (or division). Notify the Chief of Chemical Warfare Service of all such methods in use in the unit. (e) Take steps to prevent the needless salvage by hospitals of gas equipment of patients.

Enemy Material and Intelligence. (a) Secure all material, documentary and otherwise, of any gas interest through divisional (regimental) gas personnel, the salvage officers, G-2, and miscellaneous sources, and, if practicable, by examination of enemy dugouts, dumps and positions in immediate wake of infantry advance. (b) Utilize all available means of transportation for removal of non-mailable material to nearest Advance Army Gas Depot, notifying the next senior Gas Officer or find out where it is deposited, sen ling copy of report to Chief of Chemical Warfare Service. (c) Deliver all non-gas intelligence thus secured to G-2. (d) Secure, if practicable, translation of gas documents before forwarding them when data is likely to be of immediate importance to Corps (divisions). (e) A set of enemy fuses and typical gas shell, sectioned, should be kept at the gas office for information of all concerned.

Training of Divisions. (a) When Division is in training recommend to G-3 to establish conferences of regimental and battalion gas officers and schools for gas non-commissioned officers. (b) Recommend to G-3 to

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establish a series of lectures, demonstrations, inspections and drills for the enlisted personnel of the division.

The following is a suggestive digest of the functions of a Regimental and Battalion Gas Officer. It should be noted that responsibility for all measures taken in chemical warfare, whether in offense or defense, rests ultimately upon the commanding officer concerned, and the gas officers concerned are under their command. Usually, either the commanding officer of the regiment will order his gas officer to follow the technical advice of the Division Gas Officer, or this may be ordered by higher authority. (a) Keep an accurate record of training and ability of subordinate personnel, recommending such advancement as may be merited and practicable. (b) Keep the gas personnel advised of the latest available data, holding frequent conferences and inviting suggestion and criticism. (c) Exact strict compliance with orders relating to inspection by subordinate personnel, condition of material, gas discipline and reserve supplies by means of personal supervision and frequent inspections. (d) Insure the immediate availability of authorized reserve anti-gas supplies, their suitable transportation and proper issue. (e) Advise commanding officers of the proper precautions to be taken in anticipation of gas attacks, and in the event of such attacks keep informed concerning all action taken. (f) Minimize false alarms and supervise instruction to sentries, insuring active liaison with gas personnel of subordinate and superior commands. (g) Secure sufficient first aid relief in exposed areas. (h) Furnish counsel to the Commanding Officer in gas matters and stimulate interest in and understanding of the use of gas on the part of all officers. (i) Furnish liaison between the command and gas unit operating therewith, insuring sufficient understanding by troops of nature of proposed activity of gas unit operating therewith, in order to enable them to take full advantage thereof. (j) Report accurately and promptly concerning the enemy use of gas and its effect. In case of artillery gas officers, report in addition concerning delivery of gas upon enemy objectives. (k) Secure strict compliance with zone regulations and punishment of offenders. (l) Minimize waste of anti-gas material, applying disciplinary measures to of-

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fenders and insuring the full and proper use of all anti-gas supplies. (m) Advise the next senior gas officer of the location of finds of enemy gas material or cause prompt delivery thereof to his office.

Inspections of divisions by corps gas officers and of regiments by division gas officers should be frequent and thorough thereby stimulating initiative and interest of subordinate gas personnel, furnishing basis for the removal of the unfit, advancement of the meritorious, and securing helpful suggestions for the improvement of the Service.

In general, the basis of inspection should be the determination by interview, of the activities of the Gas Officer of the unit inspected and the instructions issued by him, followed by investigation of conditions in subordinate units, and the manner in which existing instructions are complied with by the gas personnel of these subordinate units.

The Gas Officer should obtain maps and information regarding enemy dispositions and study the character of the enemy terrain with the view of selecting favorable targets for gas. He should study friendly terrain in order to select favorable positions for emplacements. Information should be obtained from the Chief of Artillery regarding the availability of guns of various types and calibers. He should also obtain from the munitions officer information regarding the material available for use. The Commanding Officer of gas troops should be consulted regarding the use of cylinders, projectors and trench mortars, their availability and the feasibility of any project which might be contemplated.

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APPENDIX 10

CASUALTIES BY GAS IN THE AMERICAN EXPEDITIONARY FORCES

ADMISSION, ENLISTED MEN AND OFFICERS

	Officers	Enlisted Men			Total Enlisted
		White	Colored	Color Not Stated	
Gas, asphyxiating	3	106	3	15	124
Gas, poisonous (Kind not stated)	1,201	26,050	535	8,277	34,812
Chlorine	32	1,654	37	199	1,890
Mustard Gas	822	23,084	482	3,480	27,046
Phosgene	415	5,693	66	939	6,698
Yperite	30	606	46	249	901
Arsine	30	350	125	94	569
Total	2,533	57,543	1,294	13,203	72,049

Total admissions from gas, enlisted men	72,040
Total deaths from gas, enlisted men	1,168
Total deaths from gas, officers	26
Total admissions, Battle injuries (including gassed) officers	8,633
Total admissions, Battle injuries, Enlisted men (including gassed)	231,873

Figures include all reports rendered to the Surgeon General from the American Expeditionary Forces arriving in Washington before June 1, 1919. Do not include any killed in action. Add 200 dead of gas on field

COMPARISON BASED ON OFFICIAL FIGURES

Total Gas Casualties	75,767
Total of all Casualties	273,869
Percentage of Casualties, due to Gas	27.6%
Total deaths due to Gas	1,194
Percentage of Gassed Cases, resulting in death	1.5%
Percentage of battle wounded cases resulting in death (47,715/165,933)	28.7%
Percentage of battle deaths due to Gas (1,194/48,909)	2.4%

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APPENDIX II

ANTI-GAS MEASURES AFFECTING SPECIAL ARMS

It is unlikely that Cavalry, when mounted, will encounter high concentrations of gas from a gas cloud, or even from gas shells. It will probably be found therefore that, when acting as mounted troops, the P. H. helmet will be adequate protection, besides being less cumbersome for troops depending on their mobility.

On the other hand, Cavalry used to supplement Infantry in the line, or employed as working parties in or near the trenches, must be equipped for gas defense in the same way as other arms. In this case, it is impossible to wear the bandolier over the shoulder when the box respirator is worn in the "Alert" position. During the Gas Alert period, mounted troops must therefore wear the bandolier round the waist.

Artillery are probably more liable than any one else to bombardment with gas shells, both poisonous and lachrymatory. Owing to the suddenness of shell attacks and the long period that the neighborhood of a battery may be affected by lachrymators, it is essential that the following points be noted:

(a) Where, owing to circumstances, box respirators are not actually worn on the men, they must be hung separately and within easy reach of the owners. (They should not, if possible, be hung in the actual gun emplacements, owing to the concussion being liable to displace the chemicals in the box.) If this course has to be adopted, the respirators should be ready prepared with the haversack sling shortened by means of the tab and stud and the slack of the sling tucked under the mask as in the "Alert" position. The satchel flap should be unbuttoned, but kept in position.

(b) Men must be well practiced in wearing their box respirators for long periods and in serving their guns while wearing respirators or anti-gas goggles.

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Forward observing parties must take all the precautions laid down for Infantry.

The following precautions apply to medium and heavy trench mortars as well as to guns and howitzers: Batteries which are in constant danger of gas attacks, whether from gas clouds or gas shells, should keep all bright parts of the gun or mortar, carriage, mounting and accessories well coated with oil. Sights and all instruments should also be smeared with oil and protected with covers when not in actual use, care being taken that the oil does not come in contact with any glass or find its way into the interior of the instrument. Cartridge cases of the ammunition stored with the battery and all uncapped fuses, or fuses which have been removed from their cylinders, should be wiped over with oil as soon as possible and protected with a cover.

All bright parts of guns and trench mortars, together with all accessories and spare parts exposed to the gas, must be cleaned and wiped dry as soon as possible after the attack, and in any case within 24 hours, after which they should be thoroughly coated afresh with oil. The same applies to the whole of the ammunition still in the battery position. Ammunition which, for any reason, had not been oiled, must be cleaned and oiled. It is desirable to expend it as soon as possible.

Aiming points and aiming posts are liable to be obscured by the gas cloud and arrangements should, therefore, be made in every battery to meet this eventuality by providing gun pits with means to check the line of fire if necessary, without depending on the use of aiming posts.

Enemy gas attacks may be executed for purposes other than the preparation of a subsequent infantry attack. During the gas discharge a heavy artillery fire on the actual trenches whence the gas is issuing is the best way of dealing with the situation. Also it is essential that the gas discharge should be interfered with as early as possible, as the opening periods of the discharge are the most effective.

To insure an effective and immediate artillery fire the following points require attention: (a) Certain howitzer batteries should be detailed to open a rapid fire

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for a short time as an anti-gas measure. (b) Only certain portions of the enemy's front trenches can be used for gas discharge in any given wind and these can easily be indicated on any accurate trench map. Each battery charged with the task of hampering an enemy gas attack should be provided with a map and a table, showing from what portions of the enemy's lines (within the battery's zone of action) gas can be discharged in any given wind. Nothing in the foregoing in any way affects the responsibility of artillery for dealing with any infantry attack, or for the execution of counter-battery work.

Tunneling companies are again reminded that neither the box respirator nor the P. H. helmet affords protection against mine or explosion gases. Owing to the difficulty in clearing gas, especially lachrymatory gas, from mine-shafts and galleries, the entrances to mine-shafts should be protected from gas by blanket curtains in the manner described for dug-outs. The enemy has occasionally attempted to render the galleries untenable by the use of lachrymatory bombs in conjunction with the explosion of a charge. If this is done, goggles will generally be found sufficient protection; but if the concentration is so high as to affect the nose or lungs, the box respirator must be worn if work has to be continued.

It is essential that telephone operators should be able to work as much as possible during a gas attack without wearing respirators or helmets. Signal dug-outs must, therefore, be particularly carefully protected against gas, so as to allow this to be done. Telephone operators must be specially practiced in using their instruments when wearing box respirators or helmets. The head-piece of the receiver will be worn over the helmet. The buzzer should be used when the respirator or helmet is worn. Linesmen must receive plenty of practice in carrying on their work, both at night and in the daytime, while wearing box respirators and also goggles.

The only effective method of preventing corrosion of electrical apparatus during a gas attack is to prevent the gas reaching it, and the best way of doing this is to have the signal shelters and offices thoroughly protected against gas. As the corrosive effect on damp instruments is very much greater than on dry instruments, the shelters

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should be kept as dry as possible. During a gas attack telephones must be kept in their leather cases and unless the buzzer key is being used the leather flap must be kept down, leaving only the cords with receiver and hand-set out of the case. The backs of switchboards and buzzer exchanges must be kept closed. All apparatus, such as magneto telephones, test boards, spare instruments, etc., which it is not essential to have uncovered, should be well covered up with cloths, blankets or coats, etc.

After a gas attack, telephone apparatus that has been exposed to gas should be treated as follows: The ends of the wires should be removed from terminals and cleaned by being scraped with a knife, wiped with a damp cloth and dried. Terminals, exchange plugs and all exposed metal work should be cleaned first with a damp and then with a dry cloth. This process should be repeated after 12 hours have elapsed. The metal work of the leather case of the telephone and of other instrument cases should be cleaned with oil in the same way as rifles, etc. The internal portions of the instruments should not be interfered with. If an instrument has been kept closed or covered up, it is very unlikely that internal portions will have suffered; but if these portions show signs of corrosion, the instruments should be sent back to Division or Corps Headquarters to be dealt with by an instrument repairer.

When the gas alarm is sounded, all baskets containing pigeons should be placed in the special anti-gas bags provided for this purpose, or placed in gas-proof shelters. If for any reason the birds cannot be protected from the gas, they should be liberated at once. Anti-gas bags should always be kept near baskets containing birds, and should be regularly inspected. Pigeons can be utilized during a gas attack. Experience has proved that they fly through any gas cloud, but it is imperative that the bird should be exposed to the gas for as short a time as possible. The message and carrier should, therefore, be prepared and if possible, fastened to the pigeon's leg, before the bird is exposed to the gas. Twenty seconds should suffice to fix a carrier and liberate a bird.

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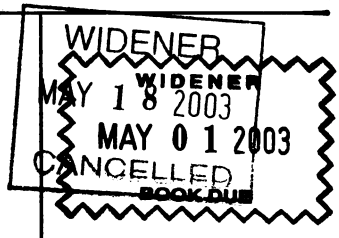

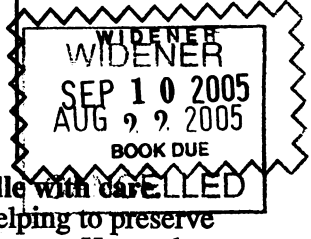

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